CALIFORNIA STATE MINING BUREAU.

J. J. CRAWFORD, State Mineralogist.

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MINE DRAINAGE,

PUMPS, ETC.

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Mechanical Engineer.

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LETTER OF TRANSMITTAL.

HON. J. J. CRAWFORD, *State Mineralogist:*

DEAR SIR: In pursuance of your instructions, I have prepared this Bulletin of the State Mining Bureau, treating of the most important applications of water-raising machinery for the drainage of mines. It has been my aim to make this a short, popular exposition of methods, constructions, and principles involved in the machines used in the extremely varied conditions of mining on the Pacific Coast; and, in view of the modern improvements and facilities in the transmission of power, which may make advantageous the use of machines not now employed in mine drainage, these have also been given consideration. The amount of ground covered in the treatment of each subject has necessarily been limited. The principles governing the design and operation of apparatus have, however, been given at some length, in order to render them clear. Only where absolutely necessary has use been made of mathematical expressions, and these most simple.

The old Cornish and other non-rotative engines applied to the so-called Cornish system, which are to-day practically obsolete, have received only the brief notice due from the standpoint of historical reference, and where necessary to explain motives for improvement of methods. As akin to the general subject, water-raising machines applied to other uses than mine drainage are incidentally mentioned; and in an appendix will be found some remarks on the appliances used in irrigation and land drainage.

Among the difficulties encountered in preparing a work of this nature, and which cause delay in its completion, are those of obtaining correct data with reference to the practical working of apparatus, and reconciling contradictory statements of results.

While a large number of the illustrations were made from designs prepared by the writer, many are reproductions from domestic and foreign technical journals. A large proportion, however, are from engravings kindly loaned by manufacturing firms and other parties here and elsewhere. The thanks of the writer for such courtesies are due to the Union Iron Works, Fulton Engineering and Shipbuilding Works, Pelton Water Wheel Co., Dow Pump Works, Crane Co., Parke & Lacy Co., Dunham, Carrigan & Hayden Co., Joshua Hendy Machine Works, Excelsior Wooden Pipe Co., G. M. Josselyn & Co., and Krogh Manufacturing Co., all of this city; Fraser & Chalmers and the Gates

Iron Works of Chicago, Henry Worthington Co. of New York, Knight & Co. of Sutter Creek, A. Chavanne of Grass Valley, A. McCone of Virginia City, and Knowles Pump Works of New York.

The works of Von Hauer, Weisbach, Riedler, and others have been freely consulted in preparing this Bulletin. The writer is also indebted to his friend and colleague, W. R. Eckart, M.E., for some valuable negatives from which cuts were prepared. Special thanks are due his friend Ross E. Browne, E.M., for valuable advice in many cases.

I herewith acknowledge my obligations to yourself for careful revisions of the manuscript and valuable suggestions on the arrangement of the book; and also to Statistician Charles G. Yale for assistance in the preparation of the manuscript and its editorial revision.

Inasmuch as there has not been any comprehensive treatise on this subject within reach of the majority of the miners of this State, it is expected the present one will prove to be of interest and value. If it shall have the effect of a better understanding of the methods and principles involved, the writer will feel he has contributed his mite to the general advancement of the most important industry of his native State.

Respectfully,

H. C. BEHR, M.E.

SAN FRANCISCO, *August*, 1896.

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By HANS C. BEHR, Mechanical Engineer.

INTRODUCTORY.

CONTROLLING THE WATER IN MINES.

Mines worked through shafts are subject to flooding by penetrating water-bearing ground. Even if not encountered at first, water is liable to be struck at any time, and appliances should therefore always be in readiness to handle it. For moderate inflow the water can generally be hoisted in bailing-tanks without encroaching too much on the time required for other hoisting operations. When, however, a large permanent flow is struck, the entire hoisting capacity may be required for bailing until a suitable pumping-plant can be installed.

In deciding upon the capacity of a proposed pumping-plant, it is necessary to ascertain as nearly as possible the maximum quantities of water that may be encountered at different levels. In well-opened mines this can generally be done without difficulty; not so in sinking a shaft in new ground. But, if other mines are adjacent, a record of their water production is a very good guide.

The pumping-plant should be able to handle a much larger quantity of water than any recorded maximum, so that a considerable increase can be taken care of without resorting to bailing. Bailing arrangements should, however, also be in readiness to meet at once any extraordinary increase that may occur at any time.

The water is generally found in a mine at various levels, and, where economy rather than simplicity is the object, any considerable quantity of water should be collected and led to pumps at the levels where it issues, and not be permitted to first find its way to the bottom, from where it would have to be raised the entire height to the surface, thereby increasing the cost of pumping in proportion to the increased lift for that part of the water.

In many mines, the quantity of water varies, not only as new bodies are tapped or opened ones drained, but also with the seasons of the year; and observations extending over at least a year should therefore be available for fixing on the capacity of a pumping-plant. In the Kennedy Mine, Amador County, California, the water production varies from 75,000 gals. per day during the dry season to 150,000 gals. during the wet season, and is handled by bailing-tanks.

The generally variable nature of water inflow necessitates a corresponding variation in the work of the water-raising apparatus. Bailing adapts itself most readily to such variation, as it gives equal though low mechanical efficiency for a very wide range of capacity. With pumps the case is different, since the number or length of strokes can only be varied economically within certain limits.

Mine pumping-plants should be designed and constructed with the aim of obtaining the greatest possible security against breakdowns, and at the same time admitting of rapidly making repairs and replacing worn parts. If possible, the pumping-plant should also be so designed that it will give the highest mechanical efficiency for that rate of flow which prevails most of the time and furnishes the largest proportion of all the water. Large excess over this, if known to be of short duration, can be taken care of by bailing-tanks or cheaper and less efficient emergency-pumps. A sudden influx of large quantities of water can be handled by bailing with powerful direct-acting hoisting engines, which bring the tanks to the surface rapidly. Often a mechanically less efficient plant may, owing to other conditions, prove to be commercially the most efficient.

Timbered shafts are universally used in the West. They are generally arranged with three compartments—two for hoisting, and one for the pumps. The latter should be partitioned off from the hoisting-compartment, so that it can be made to serve as upcast to ventilate the bottom of the shaft, because the pump-shaft is usually warmer than the hoisting-compartments, due either to steam-pipes for operating direct-acting pumps, or to the warm water in the column-pipes.

Where the mine has two separate shafts connected below, so that one serves as upcast shaft, the pumps should, if possible, be placed in the latter.

The kind of pumps, source of power, and the means of transmitting this to the pumps underground, depend on surrounding conditions, and only a careful study of these can decide the proper kind of plant to be adopted.

SECTION I.

GENERAL FEATURES OF MINE PUMPING-PLANTS.

CHAPTER I.

Preliminary Remarks on Mining Pumps.

1.1.01.* *Water-Raising Machines Used in Mining.* The pumps used in pumping out mines are chiefly reciprocating. Centrifugal pumps find some application for low lifts, and generally in open workings. Of other water-raising appliances used, the bailing-tank is the principal one, and finds a wide range of application. Pulsometers are used as a low-lift auxiliary to pumps, etc. The same is true of ejectors. It is also occasionally possible to employ siphons for raising water over an eminence.

1.1.02. Reciprocating pumps may be divided into plunger, piston, and bucket (or lift) pumps.

1.1.03. The oldest pump used in mines is the draw-lift pump, with a valved bucket working in the barrel. The modern forms of this type of pump are much used for sinking where the pumps are operated by rods. They are not suitable for working against heads of over 200′. The pump-barrels and bucket-packing also are exposed to great wear, particularly when the water carries sand. The bucket cannot be packed while the pump is running. Nevertheless, their use in mining is very extensive. In the Cornish system they are generally arranged so that the bucket can be hauled up through the column-pipe for repairs.

1.1.04. Plunger, or force, pumps are suitable for much higher lifts. Vertical, single-acting plungers are the typical form of the modern pumprod system. In these the plunger-packing can be taken up while the pump is running, and, as the packing is located at the highest part of the pump-barrel, away from the course of the water, little sand or grit is liable to reach it. The pump can, therefore, run quite a long time before repairs are required at that point.

1.1.05. Horizontal, double-acting plungers are generally used for high-pressure, direct-driven pumps. These are arranged either with or without cranks and flywheels. In the former case they are called direct-acting pumps; in the latter, rotative pumps. Flywheel, or double-crank pumps of this class, with mechanically actuated valves designed by Riedler, have been used continuously for single lifts of 1,300′.

1.1.06. Piston pumps are suitable only for lower pressures. The piston-packing and cylinder are subject to wear, while the pump must be stopped and the piston taken out to pack it.

1.1.07. Centrifugal pumps are, as generally constructed, only suitable for low lifts, but are capable of handling large volumes of water.

* The numbers at the beginning of the paragraphs are so arranged that the first figure denotes the *Section*, the next two figures the *Chapter*, and the last two the *Paragraph*. Thus, 1.5.17, means the 17th Paragraph in Chapter V of Section I.

As they have no valves, the water may contain large quantities of sand and gravel without impairing the efficiency of the pumps while they last. The capacity of centrifugal pumps can only be varied economically within very narrow limits, as they require to be run at a certain speed to pump against a given head.

1.1.08. Injectors, pulsometers, etc., are not economical water-raising machines, and can only be considered as temporary appliances or as substitutes for better apparatus during its repair. The steam used to operate them acts so that a large proportion of its energy is wasted by being applied to heat the water which they deliver. For admissible application, see 2.3.33.

1.1.09. *Conditions Affecting the Working of Pumps.* The operation of pumps is influenced by many conditions: the height above sea-level; the barometric pressure; the temperature of the water pumped; the size, length, and course of the suction- and delivery-pipes; the area, weight, and lift of valves; etc. The height above sea-level, and therefore the existing atmospheric pressure, limits the height to which water may be drawn by suction or the velocity with which it will follow the piston or plunger, thereby limiting the speed of the pump for a given suction lift. The higher the temperature of the water the less will be the admissible suction lift, because if the reduction of pressure at the upper end of the suction-pipe be sufficient, the water will begin to boil at a temperature much below that at which it would boil under atmospheric pressure, and give off steam, which will fill the pump-barrel, instead of the water doing so. The suction lift must therefore be kept so low that the pressure will be sufficient to prevent steam from forming. The suction height is the vertical distance from the level of the suction water to the highest point of the piston displacement and spaces connected with it. The greater also the head pumped against the less is the admissible speed, because with the longer column shocks are more severe.

1.1.10. The influence of the pipes connected with pumps on their action is treated of in the succeeding chapter.

1.1.11. The effect of different constructions of valves is also relegated to another chapter, and is further considered in connection with the various pump constructions described in other parts of this paper.

1.1.12. *Starting Pumps.* In starting a reciprocating pump it is necessary to remove the air from the pump-barrel and the spaces communicating with it. Where these waste spaces are large compared with the piston or plunger displacement, and the head pumped against is high, the air, particularly in high altitudes, will not be sufficiently compressed on the working-stroke to lift the discharge-valve and escape into the discharge-pipe in case it is full of water. Again, if atmospheric pressure exist at the beginning of the suction-stroke, the air in the pump may not be sufficiently expanded and lowered in pressure on completion of the suction-stroke so that the outer air can lift the water in the suction-pipe, cause it to force open the suction-valve, and enter the pump.

1.1.13. *Priming and Draining.* The operation of expelling the air from a pump and filling it with water is called *priming.* Means are generally provided in a by-pass pipe with a cock for priming the pump

from the discharge-pipe in case the latter already contains water, the escape of air being then generally effected through a cock near the highest part of the space communicating with the working-barrel. When no air-escape is provided, the air will be forced out through the discharge-valve into the discharge-pipe, as soon as the pump is put in motion. When there is no water in the discharge-pipe, pumps with large waste spaces generally require independent means for priming them, such as an opening with a funnel, through which water may be poured. Pumps placed below the supply from which they draw do not require priming. Pumps and pipes should be fitted with means for draining them to prevent freezing and to draw off sediment.

1.1.14. *Methods of Driving Pumps.* Main pumps for shafts are either operated through rods from a motor or engine at the surface, like in the familiar Cornish system of pumping, or, as in more modern methods, by transmitting power to motors directly coupled to the pumps, either through pipes, in the form of steam, compressed air, or pressure water, or as electricity through wires. Some one of these modes of transmission is required, where, as is usually the case, pumps or other machines are used to raise water from winzes or low places, and force it up to the nearest station-tank at the pump-shaft. Hand pumps are also similarly used to raise small quantities of water from low places into launders in the drifts. Pumps should be started in motion gradually, and not in such a manner as results from throwing them suddenly into gear with driving machinery already in motion.

1.1.15. *Distribution of Pumps.* The distribution of pumps along the line of the shaft depends, first of all, upon the lift allowable for the individual pumps. This condition determines the spacing of pumps in the Cornish system, in which they are generally 200′ to 250′ apart. Where, however, the pumps are capable of working against a very high head, as in some of the modern direct-acting types, they should, for economical reasons, be spaced according to the levels at which water issues.

1.1.16. Though the water which is generally encountered in sinking a shaft does not always issue at the lowest point, it is nevertheless usually necessary, if pumps are put in, to have the lowest pump so arranged that it can follow close to the shaft bottom as it goes down, in order to be prepared to handle any water that may be struck there, or which may flow down from upper levels. Pumps used for this purpose are called sinking-pumps.

1.1.17. When the sinking-pump has been lowered so far that the limit of its admissible lift is reached in raising water to the next higher pump, another permanent pump is put in near the bottom of the shaft. The sinking-pump then delivers its water to this lowest fixed pump, and is made ready to proceed with further sinking.

1.1.18. *Desirable Features of Mining Pumps.* The welfare of a mine, if subject to influx of water, depends largely upon the reliability of the pumps. These should therefore be so constructed and arranged that there may be the least possible chance of their failure. The following are some of the main desirable features: (1) They should be capable of running a long time without requiring packing, repairs, or adjustment; (2) They should, if possible, be capable of being operated and

repaired under water. This is particularly desirable in the lowest, or sinking, pump; (3) They should be able to handle sandy and sometimes acid water, without too rapid wear or deterioration.

1.1.19. In addition, they should be so arranged with reference to the driving power that they can be operated for a wide range of capacities to adapt them to the varying conditions of the water production of the mine.

CHAPTER II.

Pipes.

1.2.01. Pipes used in connection with mining pumps are, firstly, those for conveying the water handled by the pumps, constituting in reality a part of the pumps; and, secondly, those used for conveying power to the motors operating the pumps, in the form of pressure water, steam, or compressed air. While the main object of this chapter is to treat more at length of the former, it is proper, though perhaps to a more limited extent, to consider also the latter, as they are intimately connected with the operation and care of pumps in mines.

1.2.02. The suction- or inlet-pipes and the discharge-pipes of a pump or hydraulic pumping-engine affect the working of these to a great extent, and it is necessary to consider them in a different manner from ordinary continuous-flow water-pipes, in order to fix upon the most advantageous arrangement, size of pipes and pumps, and admissible speed of the latter.

1.2.03. *Material of Pipes.* Cast-iron, formerly used exclusively for larger pipes subjected to pressure underground, is now rarely employed in American mines for this purpose. While this material is less subject to corrosion than either wrought-iron or steel, the pipes made from it have to be very heavy with a proper factor of safety to withstand the pressure, and the sections are therefore more difficult to handle.

1.2.04. The cheapness of wrought-iron pipes, their greater security under water-hammer, and the facility with which sections of any length can be cut off and fitted to place at the mine, have led to their almost universal use in general practice.

1.2.05. In cases where the corrosive action of the mine-water on the iron pipes is very strong, and their destruction rapid, pipes of other materials have been used.

1.2.06. At the Barranca Mine, Mexico, drawn copper tubes were put in at great cost. Wooden pipes, where the pressure is not great, or, for higher pressure, iron pipes lined with wood, are sometimes used.

1.2.07. *Wrought-Iron Pipe.* Formerly, column-pipes larger than 14″ in diameter for mine use were made of boiler plate, riveted hot, often with butt-joints and lap-strips; the rivets being countersunk on the inside. Now, iron and steel lap-welded tubes up to 24″ diameter can be obtained, and manufacturers are preparing machinery for sizes up to 30″ in diameter.

1.2.08. Welded pipes are either lap-welded or butt-welded. The latter should be used only for smaller sizes, and for moderate pressure, as they are liable to split open at the weld. Lap-welded tubes or hot-

riveted pipes of boiler plate are the only wrought pipes suitable for pump-columns in shafts, and for all purposes where heavy pressures and water-hammer are encountered. Lap-welded tubes are also used for steam- and compressed-air-pipes. Iron boiler plates, including those of which welded tubes are made, have less strength in the direction of their width than their length, which latter is the direction of strain when manufactured into a welded pipe. Sheets of mild steel are homogeneous in this respect, besides possessing greater strength; therefore, for larger sizes steel pipes are nearly always used. Welded pipes may be obtained in lengths up to 20′. For the sake of facility in handling, however, the sections composing a line of pipe in a mine are usually not over 16′ in length.

1.2.09. Ordinary pipes, either lap- or butt-welded, having screwed ends for connection by threaded flanges or couplings, are classified by manufacturers according to nominal inside diameter. The actual diameter is generally in excess of nominal diameter. Lap-welded tubes connected by other means than the regular coarser pipe threads, that is, by flanges shrunk or riveted on, or by leaded joints, or finely threaded sleeves or flanges, are known according to their exact outside diameter. Such pipe is generally called tubing; when connected by fine thread, it is known as casing.

1.2.10. The different sizes of lap-welded tubing can each be obtained of different thickness of material to suit different pressures. The following table of standard sizes and thickness may prove useful for reference:

TABLE I.

Dimensions, etc., of Lap-Welded Tubes of a Prominent Manufacturer.

Outside Diameter of Pipe, in inches.	Inside Diameter of Pipe, in inches.	Thickness of Metal.		Weight per Foot, in pounds.	Bursting Pressure, lbs. per sq. inch.
		Birmingham Wire Gauge.	Inches.		
3	2.73	10	.135	4.05	5,900
4	3.70	9	.150	6.00	4,800
5	4.67	8	.165	8.40	4,200
6	5.64	7	.180	11.00	3,800
7	6.64	7	.180	13.00	3,200
8	$7\frac{5}{8}$	--	$\frac{3}{16}$	15.65	2,900
9	$8\frac{1}{2}$	--	$\frac{1}{4}$	23.10	3,500
10	$9\frac{1}{2}$	--	$\frac{1}{4}$	25.75	3,100
12	$11\frac{1}{2}$	--	$\frac{1}{4}$	31.00	2,600
13	$12\frac{1}{2}$	--	$\frac{1}{4}$	33.40	2,400
14	$13\frac{1}{2}$	--	$\frac{1}{4}$	36.35	2,220
15	$14\frac{1}{2}$	--	$\frac{1}{4}$	39.00	2,070
16	$15\frac{1}{2}$	--	$\frac{1}{4}$	42.00	1,930
18	$17\frac{3}{8}$	--	$\frac{5}{16}$	58.40	2,150
20	$19\frac{3}{8}$	--	$\frac{5}{16}$	65.15	1,970
22	$21\frac{3}{8}$	--	$\frac{5}{16}$	85.00	1,750
24	$23\frac{1}{4}$	--	$\frac{3}{8}$	93.50	1,930

1.2.11. The thickness given in the table is known as standard. Pipe can be made one or two gauges lighter, but would not come any cheaper per foot. On special orders, the pipe can be made thicker to almost any extent. Numerous experiments have demonstrated that in properly welded pipes the weld is practically as strong as the rest of the metal.

1.2.12. *Heavy Riveted Pipes* used for pump-columns should, if possible, be made of mild steel, because then they can usually be made from a single sheet, requiring only one longitudinal joint. Steel admits of this method of construction, because, as stated in 1.2.08, it has about the same strength across the sheet as lengthwise. Iron, being fibrous in its nature, and having less strength across the sheet, should therefore be bent so that the fiber runs around the pipe, in order to secure the greatest strength. As the sheets are limited in width, this necessitates making a wrought-iron riveted pipe section of several sheets riveted together by circular seams. Longitudinal seams should be double-riveted.

1.2.13. Heavy riveted column-pipe sections are usually connected by cast- or wrought-iron flanges riveted to the sections. Where laid on the ground and not liable to be disturbed, they are often connected by lead-caulked joints, with cast or wrought-iron rings to hold the lead.

1.2.14. Riveted sinking-columns, inside of which a pumprod works as in the Cornish system, should have the rivets countersunk on the inside, and the circular seams made as butt-joints with outside lap-strips, so that the lift-pump-bucket can be drawn up and lowered through the column-pipe wihout catching on obstructions.

1.2.15. *Light Riveted Pipes** are used principally for water supply for power or for hydraulic mining where the pressure is constant and where the pipe is not subject to being crowded out of line, as in a shaft. The sheets, rarely thicker than $\frac{1}{8}''$, are riveted up cold, often, on account of transportation, at the point where put in use. They are now almost universally made of steel. If made of iron, the sheets must, for reasons previously stated, be bent in the direction of the fiber. The longitudinal seams should be double-riveted. The lengths of pipe, except for very heavy pressure (when both internal and external sleeves caulked with lead are used), are generally joined by simply slipping the ends into each other like the sections of a stovepipe. The sections are made larger at one end for this purpose. These pipes will stand considerable pressure when it is constant, but they are not suitable for withstanding any water-ram. Iron pipes of this kind have been subjected continuously for many years to a constant fiber-stress of 17,000 lbs. per square inch on the section of the sheet. At the line of the rivets, where their insertion reduces the iron section of the sheets, the stress would in that case be about 22,000 lbs.

1.2.16. *Wooden Pipes*, made of staves like a continuous barrel, hooped with steel bands, as in Fig. 1, have been in use for a number of years in connection with irrigation and gravity water supplies for cities. They are economical, especially for light pressures, and may be used for pressures of 200′, if steady, the spacing of the bands varying with the pressure. They are very smooth on the inside, and offer little resistance to the flow of water. They are not suitable for pump-columns, but there are cases in mining where this class of pipe can be used to advantage. The water does not come in contact with the steel bands, and cannot corrode them; and if the pipe is continuously filled with water, the wood will at all times be saturated and cannot decay. Where

*This class of pipe has been ably discussed by Hamilton Smith in his "Hydraulics," and also by Aug. J. Bowie in his "Practical Treatise on Hydraulic Mining." Numerous examples of (completed) pipe-lines, with experiments on flow, leakage, and stress on material, are given in those two works.

ipe-line is required in a mountainous country, difficult of access, it
n advantage that the parts of which this pipe is composed are all
ht, can be closely packed, and easily transported. The entire pipe-
e can be taken down without any injury to its parts, and be re-erected

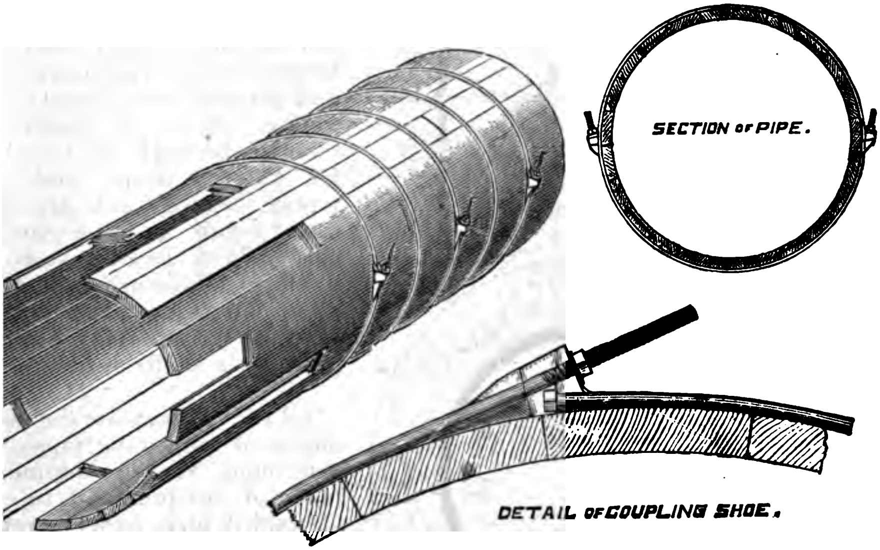


FIG. 1.

FIG. 2.

ewhere. These pipes do not contract and expand with heat, and can,
necessary, be left on the surface. The pipe is very rigid and not
adily flattened by snow or landslides. Fig. 2 is a view of a completed
pe-line of this kind.

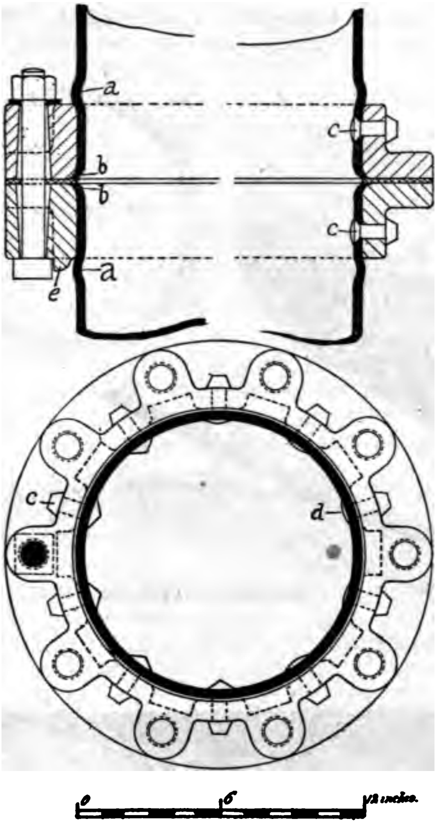


FIG. 3.

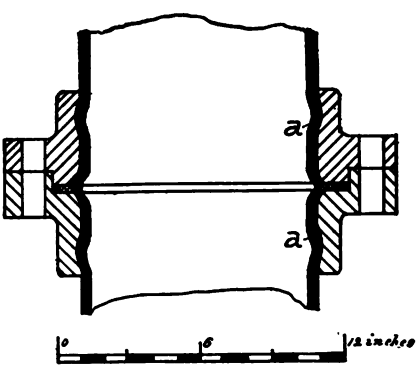


FIG. 4.

1.2.17. *Pipe Connections.* Wrought-iron pipes are connected principally by flanges, screwed ends and couplings, leaded or cemented sleeves, or by simply slipping the smaller end of one length into the larger end of the next. In underground work, shafts, etc., welded tubes with flanges or screwed connections are used for water-, steam-, and air-pipes. Leaded joints are only used where a water-pipe is permanently located and not liable to be disturbed, such as pipes for water distribution. They are not suitable for pump-columns in shafts or inclines.

1.2.18. *Flanges* are the usual means of connecting pipes underground. They are commonly made of cast-iron, and, in case of welded pipe, either screwed or shrunk on the ends of the tube, which, in the latter case, is expanded behind the flange, as at *a*, Fig. 3, and then beaded over in front, as at *b*. Instead of expanding the pipe behind the flanges, it is preferable to have the bore of the flange recessed, and to hammer the pipe into the recess, as shown at *a*, Fig. 4. This gives a firmer hold on the flange. It is sometimes necessary to put in rivets, as at *c*, Fig. 3, in case of riveted pipe or where the pipe-line is subject to lateral disturbance. Flanges for sinking-pumps, where the pumprod works inside of the pipe, should have these rivets countersunk on the inside, as at *d*, Fig. 3. In putting flanges on pipes care must be taken, in the first place, to have their faces come square with the pipe, and also to have the bolt-holes of the two flanges in line, so that the lengths of

a column or pipe-line are interchangeable. In order to allow for inaccuracies in this respect, and also to provide for possibly required variations in position of elbows or other connections, the bolt-holes are sometimes made oblong, as in Fig. 5, so that one flange can be slightly rotated upon its mate. In this case a wrought-iron washer must be placed below the nut to give it an even bearing. Such a washer is an

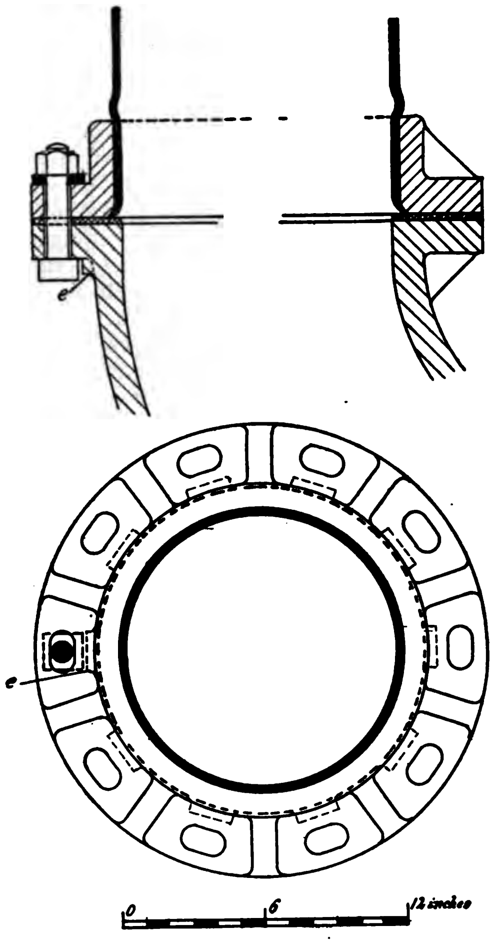


FIG. 5.

advantage also for ordinary round holes, as it provides a better bearing for the nut than the rough casting. A projection *e*, Fig. 3 and Fig. 5, should be cast on one flange of each pair, to absolutely prevent the bolt from turning when the nut is screwed up. Where it is desirable to get the flanges of as small diameter as possible, bosses are carried up around the bolt-holes to the full depth of the flange, Fig. 3. In this way the bolts can be brought closer to the body of the pipe than in the form shown in Fig. 5, while the thinner metal between the bosses affords facility for riveting to the pipe. Flanges of larger diameter are, how-

ever, always required where the pipes connect to cast elbows or nozzles, so as to allow room for the bolt-heads or nuts on the back of the flange of the casting. (See Fig. 5.) Where a greater number of such connections are required, it is sometimes preferable to make all the flanges of the larger size. Such flanges should be ribbed between the bolt-holes. Nearly all flanges obtained from dealers in pipe are much too light, and have too few bolts to be suitable for pipes subjected to heavy pressure and deflecting strains, like pump-columns or high-pressure steam-mains.

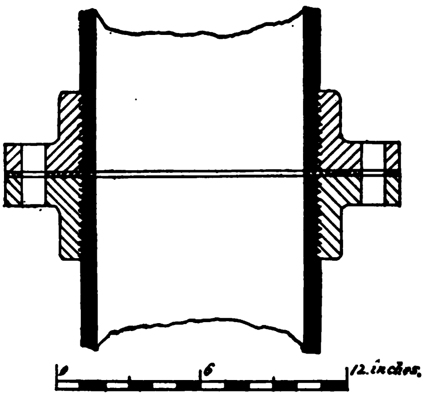


Fig. 6.

1.2.19. The smaller sizes of pipes, and often larger ones also, have their ends threaded, and are connected together by threaded sleeve-couplings or by flanges screwed on. The flanges of large steam-pipes are often put on in this manner. This method of securing flanges is generally also necessary for pipe of extra thickness. Where a tight pipe is required under high pressure, the ends are sometimes screwed through the flange, so as to project beyond its face, and then faced off level with the flange. This is a good plan for high-pressure steam-pipes where leaks are liable to occur at the threads. By the construction described, and illustrated in Fig. 6, it will be seen that the packing entirely prevents leakage at the thread by covering the joint between pipe and flange. Ordinarily a putty of red lead is used with threaded joints. For air-pipes, shellac varnish makes a very tight joint.

1.2.20. A water-tight threaded joint may also be secured by cutting away a portion of the thread, as at x, Fig. 7, and wrapping hemp or wicking into the groove before screwing into place. This joint is stated to be water tight under heavy pressure, even when the thread is so loose that the pipe can be rotated by hand. For column-pipes of Cornish pumps screwed flanges are not generally used; nor are they used in such cases where it is occasionally necessary to cut pipes to lengths, and where screw-cutting machinery of large size is not at hand. Where flanges are used on riveted pipe they are not shrunk on, but simply riveted to the pipe, and the latter caulked, if the metal be sufficiently heavy.

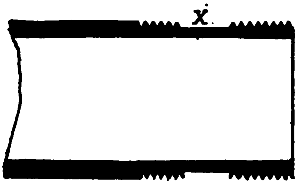
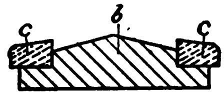


Fig. 7.

1.2.21. A flange connection which has been used with success in English collieries, is shown in Fig. 8. The ends of the tubes are expanded after the flanges *a a* are slipped on. When put together the double cone-ring *b*, with packing *c c* encircling each end, is inserted, and the bolts in the flanges drawn up. This joint has been used for water and steam; for the former, under pressures up to 4,000 lbs. per square inch. The inside ring and the outer flanges are not machined.

1.2.22. *Leaded Joints.* Leaded joints are usually adopted on pipes which are not liable to be disturbed in position, such as those for water supply on the surface. For such cases they make the most suitable



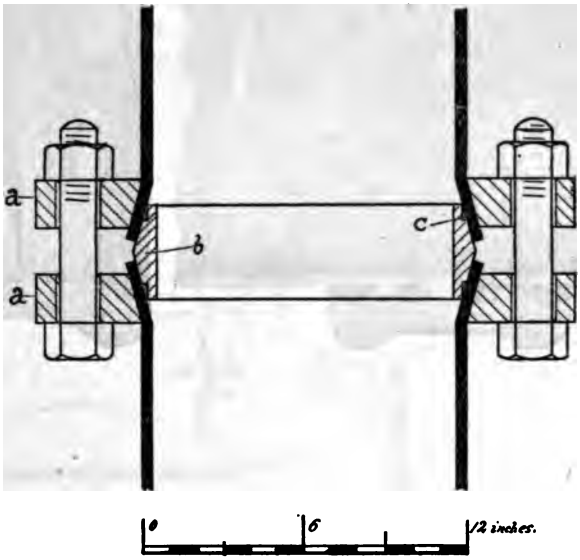


FIG. 8.

joint. The lead serves both for securing the connection and as packing. A lead joint much used for riveted pipe is shown in Fig. 9. The ends of the pipes abut on each other; and an internal sleeve prevents the lead from flowing into the pipe. An outer sleeve, usually welded, holds the lead, and must be sufficiently strong to resist pressure and caulking. Fig. 10 illustrates the Converse patent leaded sleeve-joint for wrought-iron pipe. The rivets serve to lock the pipe into the sleeve by their entering the recesses shown in the cut. Fig. 11 illustrates the pouring clamp, which fits the pipe and sleeve, and does away with the necessity of clay to form a mold for the lead when poured. After pouring, the lead is caulked firmly into place.

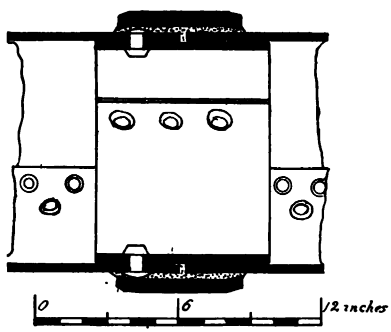


FIG. 9.

1.2.23. *Packing.* The material commonly used for securing tightness of flanged steam- and air-, as well as water-pipes, in mines, is the so-

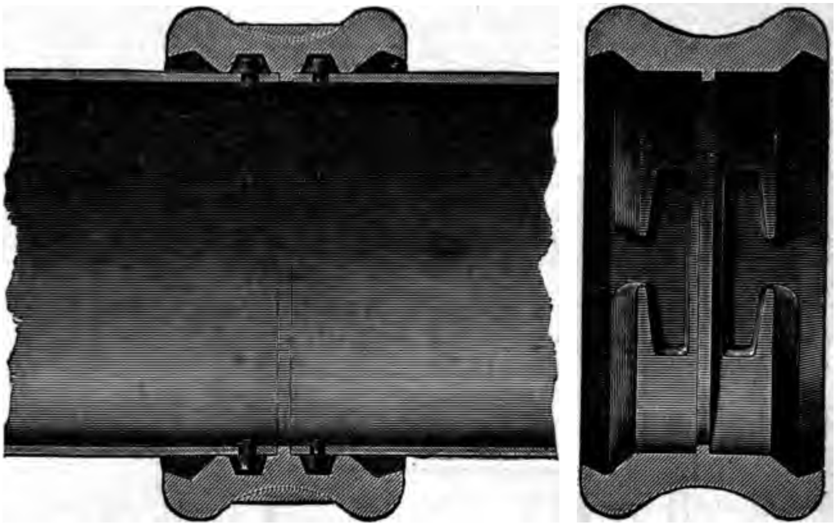


FIG. 10.

FIG. 11.

called sheet-rubber packing, composed of alternate layers of rubber and canvas. For water-pipes the gaskets are made of a thickness, ranging from $\frac{1}{8}''$ for small pipes, to $\frac{3}{16}''$ or $\frac{1}{4}''$ in larger pipes. Where the flanges are rough, thicker rubber must be used than where faced. In steam-pipes the rubber is usually not over $\frac{1}{16}''$ thick, in order to present less surface for the deteriorating action of the steam and hot water. It is always economy to use the best grades of sheet rubber. Rubber gaskets, if they have been in place for some time, particularly where subjected to heat, adhere very firmly to the flanges, and usually tear on being removed, thus necessitating new ones. Adhesion may be prevented by rubbing graphite on the surface of the gasket before putting in place. For heavier pressure the flanges are sometimes made in pairs, "male and female," as at *a*, Fig. 4, the recess being somewhat deeper than the thickness of the rubber which is laid in it, and which is prevented from

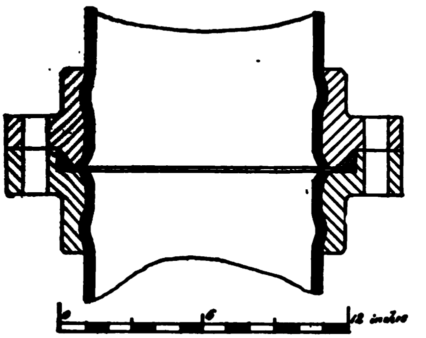


FIG. 12.

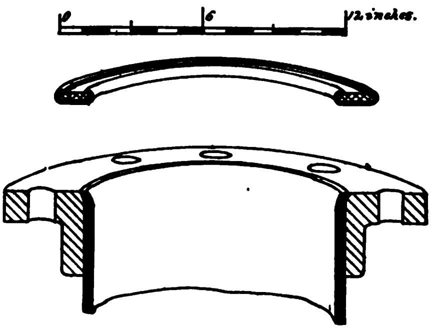


FIG. 13.

being blown out by the inclosing ring of metal. The packing shown in Fig. 12 is particularly adapted for heavy pressures, but requires continuous rubber rings, of circular or square cross-section, to obtain the best results.

1.2.24. *Lead Gaskets.* For heavy pressures, where rubber is liable to be forced out of the joint, sheet-lead gaskets are sometimes used between water-pipe flanges, these being usually machined in such a manner that their faces present a close succession of annular ridges, which sink into the lead and grip it tightly. Lead gaskets are, however, not sufficiently elastic for most purposes, and are liable to leak upon the least crowding out of line of the pipe. These gaskets are also sometimes used with male and female flanges, as shown in Fig. 4.

1.2.25. *Elastic Copper Gaskets.* A very efficient and durable gasket for steam-pipes is shown in Fig. 13. It is made of a ring of thin copper, the inner and outer edges being turned over the corresponding edges of a rubber gasket. The copper is about $\frac{1}{32}''$ thick, and the rubber $\frac{1}{16}''$. These gaskets are best made small enough to go inside the circle of bolts in the flange.

1.2.26. A flange-packing used for a head of 1,700′ at the Mayrau shaft, Kladno, Bohemia, and which has been very satisfactory, is shown

in Fig. 14. Here one of the flanges is recessed at *a* to admit a ring *b* of leather, rubber, or metal, of L-shaped section. This elastic ring is held in place by a rigid metal ring *c*, the whole forming a packing similar to that used for hydraulic-press plungers. (Modifications of this form

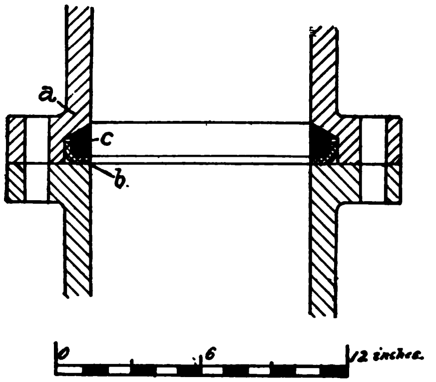


FIG. 14.

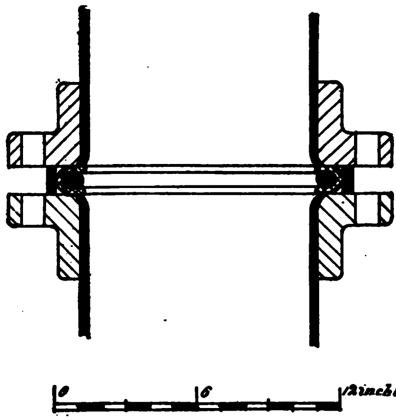


FIG. 15.

will readily suggest themselves; for example, that in Fig. 15, which could be used with ordinary flanges by inserting a forged distance-ring between them so as to form the space for the packing.)

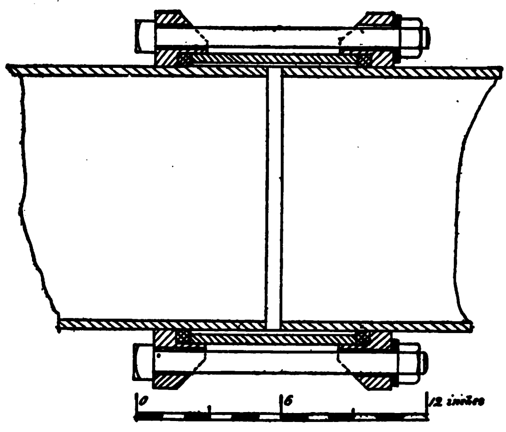


FIG. 16.

1.2.27. In the Paris compressed-air power transmission system, plain cast-iron pipes without flanges or spigot ends are used for the mains. The sections are connected by the Normandy joint, which consists of a sort of double stuffing-box, and is shown in Fig. 16. It is very flexible, and almost absolutely tight under the 80 lbs. pressure used. The pipes are not turned at the joint, but are put in as they come from the foundry. With some modifications this joint is also suitable for higher pressures in column-pipes.

Expansion Joints. For long pipes, particularly in shafts, and levels, and for pipes rigidly fixed at the extremities, ı joints must be used. The most common form of expansion joint consists merely of a stuffing-box, as shown in Fig. 17, or of a recessed spigot end containing hydraulic packing, as in Fig. 18. The end of the pipe entering the stuffing-box must be smooth, and is best made of brass. For steam-pipes in shafts, expansion joints are particularly necessary, and for these the one shown in Fig. 17 is the proper form.

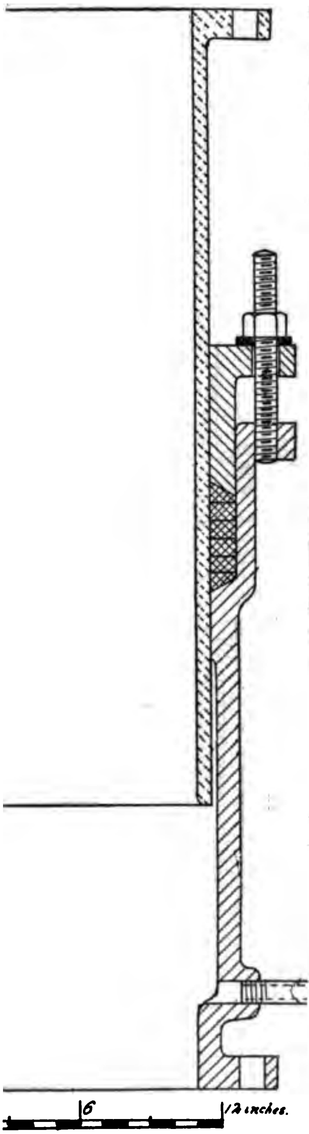


FIG. 17.

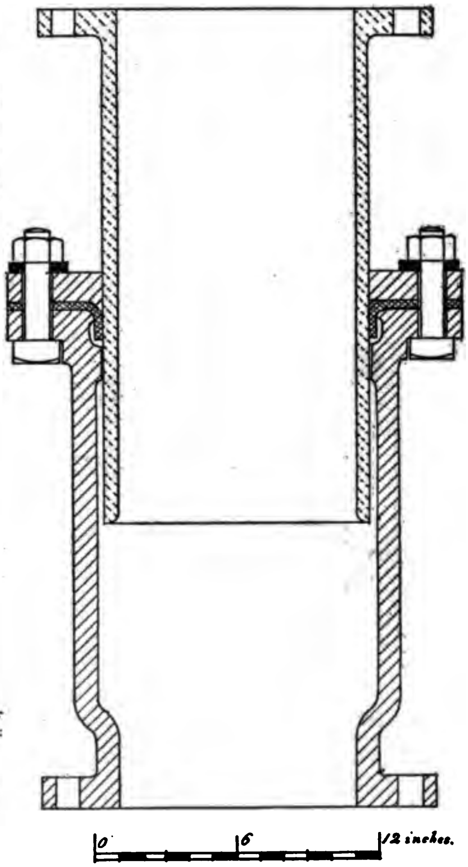


FIG. 18.

ı Fig. 18 is only adapted for water-pipes. Stuffing-boxes in d inclines should always be placed so that the gland is on top, placed otherwise, they are almost sure to leak. Expansion e usually troublesome, and should be carefully looked after.

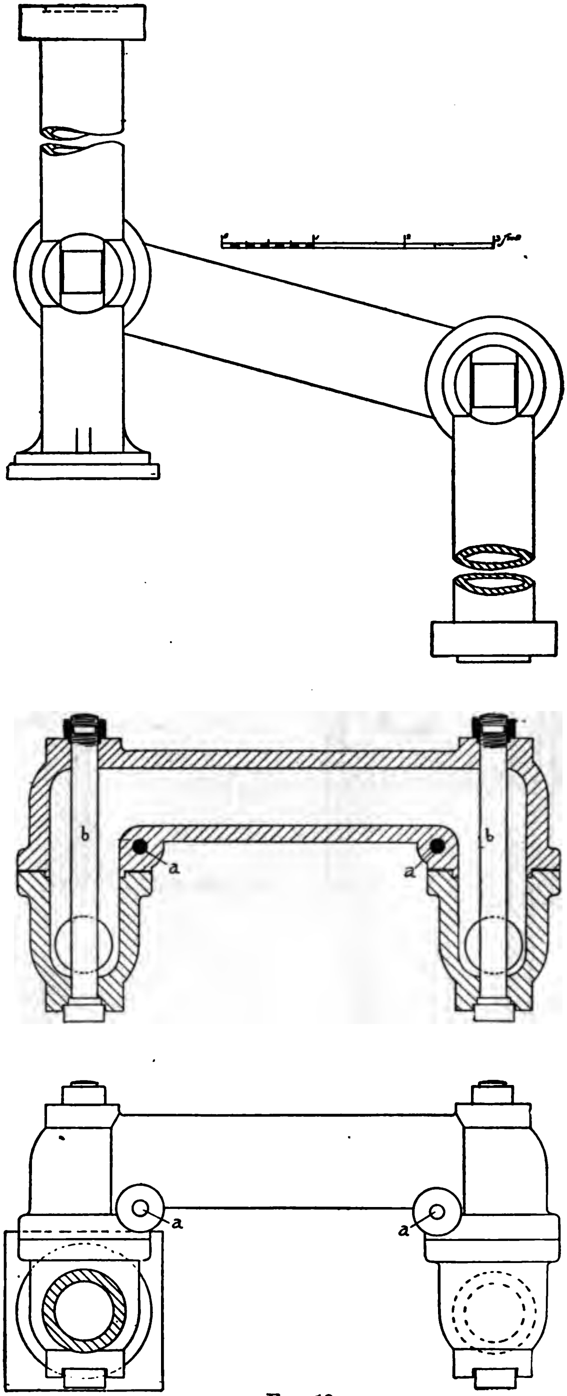


FIG. 19.

For steam-pipes, or where the water is hot, the expansion will necessarily be greater than for the ordinary variations due to climatic temperature. Both these variations can always be calculated; those due to settling of ground or timbers cannot. Ample range should therefore always be provided, so that the expansion joints will not pull out of the stuffing-box, which would be a serious matter with a steam-pipe under ground.

1.2.29. An expansion joint composed of a double swiveling pipe-section, shown in Fig. 19, was used at the "Combination Shaft," Virginia City, Nevada, on a cast-iron pipe under very heavy water-pressure, and gave good satisfaction. One of the pipes rests with a pedestal on a support in the shaft, the other being free to move. The bolts at *a* are inserted to reinforce the casting at the dangerous section. No packing was used between the faces of the casting. The threads of the swivel bolts *b* were packed by winding wicking around a groove, cutting part of the thread away. Where the range of expansion is not great, U-shaped pipes are sometimes used in steam-pipes to give them a certain amount

asticity, or a corrugated section of pipe made of copper, brass, or ght-iron is used. Such joints are, however, not suitable for long , on account of the large number required to allow for the varia- in length. Water-pipes having slip joints usually do not require expansion joints.

.30. Water-pipes laid in trenches at the surface do not require nsion joints. These are needed where pipes are laid over long ;es or trestle-work, as they are exposed to changes of tempera- Large pipes should not be car- by wire cables or suspension ;es, as both of these sway the pipe cause strains and leakage.

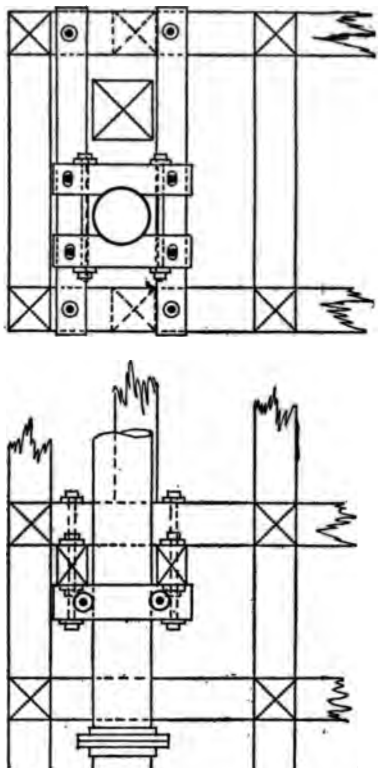


FIG. 20.

.31. *Pipe Supports.* Pipes in a cal shaft should have their weight supported, and they must also be d laterally to be kept in line. In Cornish system, with pumps not 250′ apart, the columns are lly stayed at intervals of about y clamps of wood or iron. Gen- y, these rest on beams laid across vall-plates of the shaft timbering, beams often serving at the same as supports for pumprod guides. a stay is shown in Fig. 20.

.32. Posts are frequently inserted een several sets of shaft timbers r the pipe supports, so as to dis- te the weight of the pipe on a ber of wall-plates. Sometimes pipes are clamped directly to the plates with an intervening saddle- , as shown at *a*, Fig. 21, which sents a heavy form of such a re used where a goose-neck or -pipe on the top of the pump -chamber connects to the column- The weight of the column-pipe metimes also carried rigidly by djustable bolt support (Fig. 22) ped to the pipe below a flange above the offset-pipe over the clack- ıber. There should be only one such rigid connection on the pipe, ıat the latter can expand and contract. All supports and stays ld be frequently looked after, particularly where the shaft is in bad nd and liable to be crowded out of line.

.33. Water-pipes in inclines are usually laid along the lower resting simply in wooden saddle-pieces, which serve both as weight ort and lateral stays. Steam-pipes are usually hung from the of inclines.

.34. *Bends and Elbows.* Pipes should be well supported at bends elbows, because, in addition to the effect of the weight, the unbalanced

pressure of the water tends to crowd the pipe toward the convex side. Short bends in riveted pipe are often made up of sheets riveted up like the pipe. In flanged welded pipe, short bends are made of castings. Where the velocity is great, the bends should have as large a radius as possible, especially if the bend be through a considerable arc. Slight bends in flanged pipe are often made by inserting between the flanges of two sections of pipe a ring with inclined faces, on each of which packing is placed, as in Fig. 23.

1.2.35. Elbows used with the ordinary screwed pipe have too short a bend and offer too much resistance for high velocity of flow. In case of high velocity, it is advisable, therefore, to use special fittings. The ordinary malleable iron pipe-fittings are

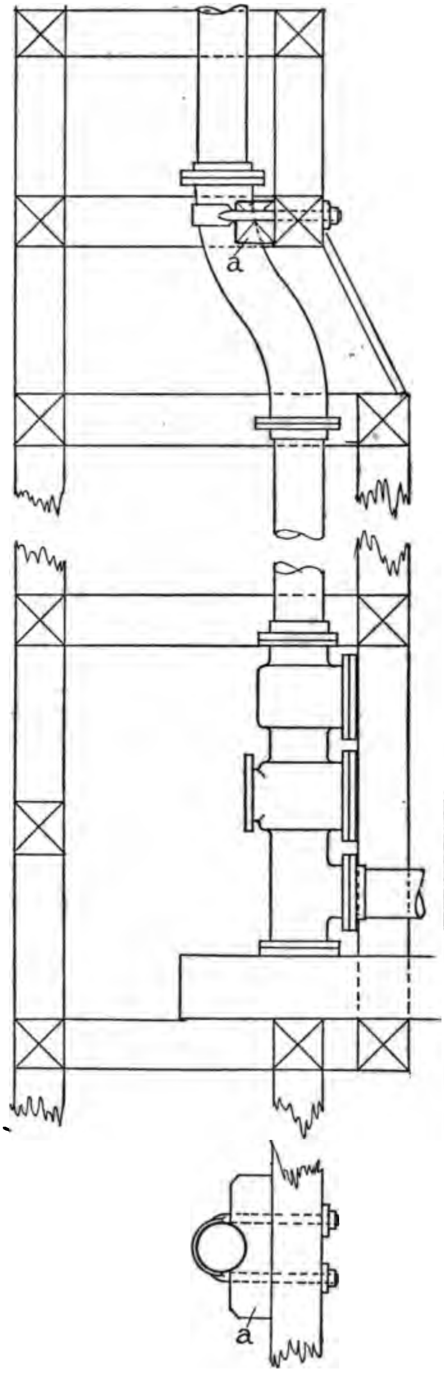


FIG. 21.

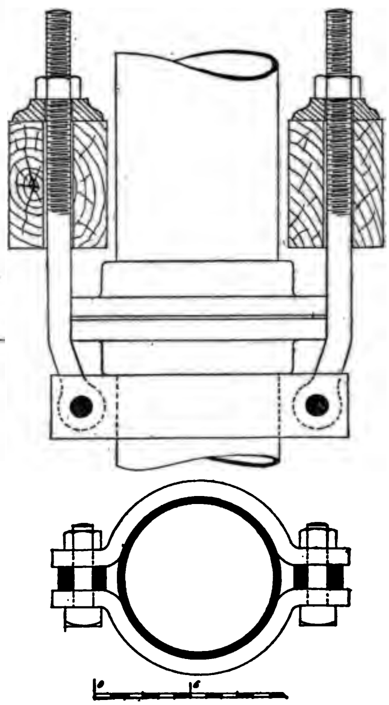


FIG. 22.

also unsuitable for many cases, and special cast-iron ones, which are less liable to split, are used for work requiring special care. Some machine shops that make a specialty of screwed-pipe work manufacture fittings of this kind, particularly elbows of larger radius than the ordinary trade fittings.

1.2.36. *Diameter of Water-Pipes, and its Relation to Velocity of Flow.* The diameter of the suction-pipe of a pump should always be such that the velocity of flow required by the speed of the pump can be maintained by the excess of atmospheric pressure plus any available head on the suction-pipe over and above the resistance due to valves and pipes. The suction-pipe, for single pumps particularly, should be as short as possible, making the mass of water which must be put in motion from rest at each stroke a minimum, so that its motion will be accelerated in the shortest possible time. Where a number of pumps operate through the same pipes in rotation or regular succession, so that the water in the suction- and discharge-pipes is always in motion, the size of the pipes may be reduced. Where the height from the suction level to the highest part of the space, the volume of which is affected by the pump-displacement, is great, the suction-pipe must be larger than where this height is small, because the available acceleration due to excess of atmospheric pressure is less. Since the mass of water to be accelerated is greater in the former case, the admissible pump speed will in general also be reduced. It is evidently necessary that all pipes be tight against leakage, but with suction-pipes this is particularly so, in order to prevent air from being drawn in, which would reduce the efficiency of the pump.

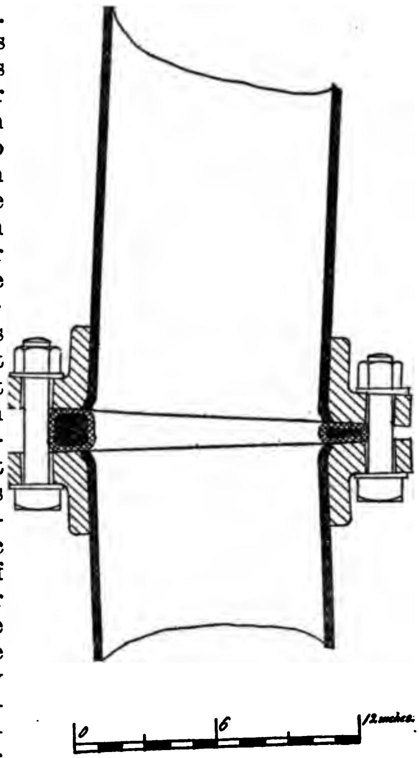


FIG. 23.

Where water is forced through a line or column of pipe by a reciprocating pump, and where, therefore, the water in the pipe is alternately started and permitted to come to rest, the velocity of flow cannot be allowed to be great; otherwise, the column of water will continue its motion for a short interval after the pumps have reached the end of their stroke, and will then fall back when the pump-piston is already on its return-stroke; the effect being to close the discharge-valve with a blow, whereby the entire column of water is arrested more or less suddenly. This is very liable to occur in the Cornish system, where air-chambers are rarely used, on account of the difficulty of applying them of proper size. In direct-acting pumps, which make a greater

number of strokes per minute, air-chambers correct this evil to a great extent by equalizing the flow of water and making it continuous.

1.2.37. The least size of pipes is sometimes determined by other conditions; as, for instance, in Cornish sinking-pumps, where it is desired to remove the bucket through the column-pipe.

1.2.38. In general, the discharge-pipe need not be larger for double-acting pumps than for single-acting ones of half the capacity, because the velocity of flow is the same, the water being, in the latter case, at rest half of the time. Greater velocity may, with the same freedom from water-ram, be given to a short column of water than to a long one. For example, where a pipe is longer than the height vertically pumped, as in inclines, or where the pipe is partly horizontal in its course, the velocity of flow should be less than for an entirely vertical pipe, and the diameter therefore greater for the same capacity, because in that

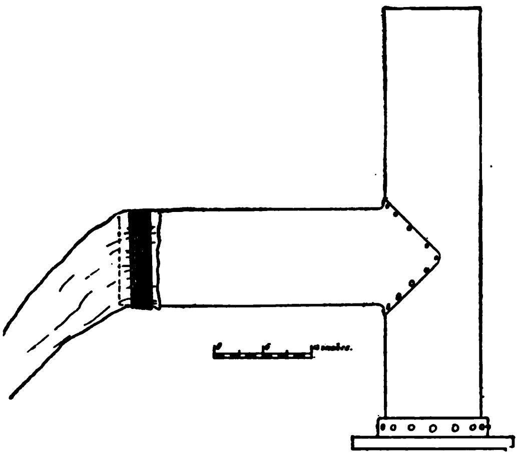


FIG. 24.

case the energy of the greater moving mass has less proportional retarding force due to gravity, and shocks are more liable to occur. Velocities over 5′ per second should not be allowed in discharge-pipes, unless a number of pumps are arranged to come to the end of their respective strokes in rotation, so that the water in the pipe will be continuously advanced. In the Cornish system the diameter of the column-pipe is frequently the same or nearly the same as that of the plungers, and, for a double line of pumps, a separate column is used for each plunger, except where the pumps act alternately on independent rods, in which case only one column need be used.

1.2.39. *Discharges and Inlets of Water-Pipes.* With Cornish pumps, particularly, the discharge from vertical or column-pipes into the station-tanks should not be by means of ordinary elbows or short bends, because the intermittent flow of the water will cause a jar by striking against the side of the elbow. It is best to carry the pipe up vertically for a few feet above the outlet-pipe, because then the water can rise freely without shock, and flow gradually from the outlet. Fig. 24 shows the usual discharge-top for column-pipes of Cornish pumps.

It is generally made of galvanized iron, for the sake of lightness in handling, and has a short piece of canvas hose attached to the outlet to prevent splashing.

1.2.40. In order to reduce losses due to resistance, inlets to pipes should be flaring (or bell-mouthed), if the velocity be great. It is also economy to gradually enlarge the outlet, and submerge the end in the discharge-reservoir, in case of high velocity, because thereby the energy of motion is changed into pressure or lift, and, in case of pumping, less of the pump work is lost. These remarks apply particularly to low lifts and considerable velocities, and where the additional lift gained is an object, on account of its considerable proportion of total lift.

1.2.41. *Thickness of Water-Pipes.* Pipes subject to uniform, constant water-pressure can be made much lighter than those subject to water-hammer, and to varying pressures due to starting and arresting the column of water, as in the discharge-pipe of a single reciprocating pump. Again, pipes which lie on the ground, and which are not liable to be disturbed, can be made lighter than those which, like the column-pipes in vertical shafts, are subject to strains from being forced out of line by moving ground. Corrosive action of the mine-water may also require extra thickness. All strains and destructive influences must be taken into consideration, in designing a line of pipe, especially in mines where delays are nearly always expensive. The column-pipes for underground pumps are therefore usually made several times the strength that would be required for a pipe-line operating under constant pressure. What applies to strains in discharge-pipes of pumps, applies, however, with greater force to such power-pipes as are used for operating reciprocating hydraulic engines, because here the shocks are liable to be even more severe than in the case of pumps. The discharge-pipes of centrifugal pumps are not so liable to water-hammer, and can therefore be considered in the same category as pipes subject to uniform pressure.

1.2.42. *Air-Chambers on Water-Pipes.* Air-chambers are frequently used along a line of pipe and at sharp bends to reduce shocks, such as occur when valves are suddenly closed or when the flow in pipes supplying water to power-wheels is suddenly arrested by obstructions finding their way into and closing the nozzle.

1.2.43. Air-chambers under pressure usually require some charging device, as the air is absorbed by the water. This device may be a small air-compressor operated by hand at long intervals, or whenever a try-cock or gauge-glass on the air-chamber shows that the air-space has become too small. Air-chambers should be so tight that no air can escape. It is well to coat them inside with paint or asphalt, for heavy pressures, as the air is liable to leak through the pores of the metal.

1.2.44. Air-chambers on pumps perform the functions of equalizing the flow in the discharge- or in the suction-pipe, and of reducing shocks on the valves. They will be considered more in detail in connection with direct-driven pumps. Spring-loaded pistons or plungers are sometimes used in place of air-chambers of small capacity.

1.2.45. *Relief-Valves.* Spring-loaded or weighted relief-valves or pistons are also used on pipes liable to sudden stoppage of the water column, so as to afford an escape for the water under excessive pressure.

Weighted valves are not so good as those loaded by springs, because they are slower to act, on account of the greater mass to be moved.

1.2.46. *Protection of Water-Pipes against Corrosion.* Pipes conveying water, and particularly those used in mines where the water is acid, are either made of material to resist corrosion, or, if the corrosion be slow, as is usual, of greater thickness, so that they will stand a reasonable time with such protection as is afforded by a coating applied to their surface. The use of copper pipes in exceptional cases has been

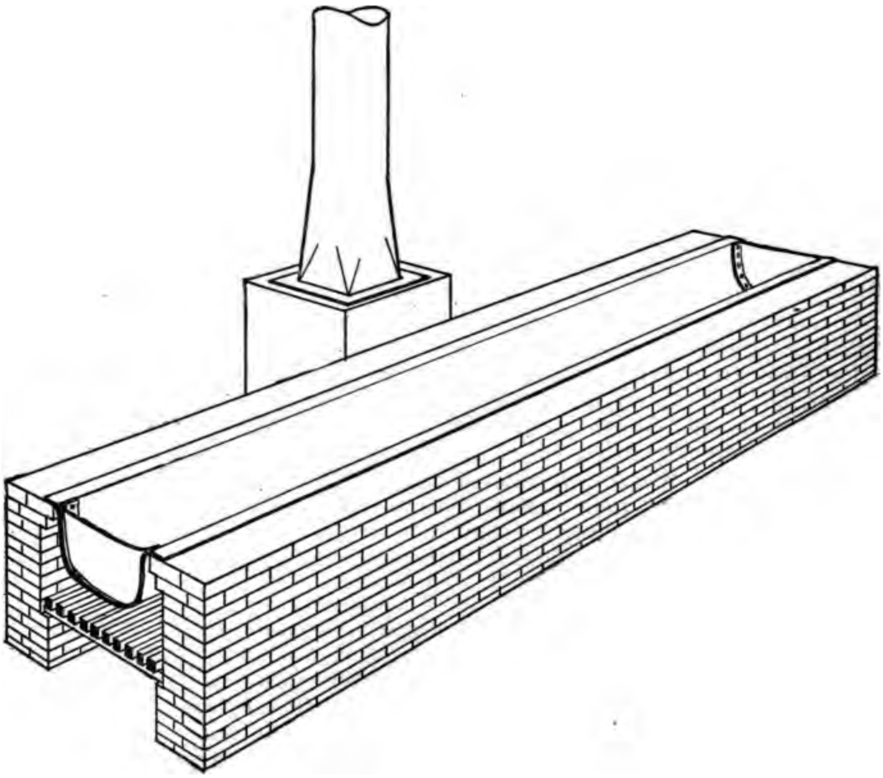


Fig. 25.

previously mentioned. They are rarely used, on account of their cost. Coatings of asphaltum, or paints prepared from the resinous part of oils, constitute the usual method of protection. The asphaltum coatings are applied by dipping the pipes into a melted bath of it. The pipes should be thoroughly heated to the temperature of the bath, and the latter must be maintained at uniform temperature. Where pipes have to be transported great distances over rough roads, the asphalt coatings are liable to be injured, and it is therefore sometimes better, if the appliances be available, to dip the pipes at the mine. Fig. 25 is a form of asphalt bath for dipping pipes. The illustration shows the apparatus arranged with a double-end fireplace under the pan. By this construction, with the chimney at the middle, more uniform heating is secured. In out-of-the-way places a pan is generally made from a spare

length of pipe by cutting it open lengthwise and riveting pieces to the ends.

1.2.47. It requires some experience and attention to maintain a uniform temperature throughout the bath with this arrangement. Where steam is available the bath can be heated very uniformly by placing steam-pipes in the bottom, in which case a wooden trough will answer as a makeshift.

1.2.48. To avoid the difficulties attending the hot coating of pipes in out-of-the-way places, the pipes are often painted or dipped cold with some of the so-called paraffine paints. The dipping should in this case be done vertically, the coating fluid being contained in a vertical pipe sunk into the ground, and only slightly larger than the pipe to be dipped, so that a minimum of surface is exposed to the atmosphere and for evaporation of the very volatile solvent. In applying any coating to pipes they must first be thoroughly cleaned, and every particle of rust scraped off, as otherwise the coating will not adhere well at such places. The asphalt coating costs generally about half a cent per foot per inch diameter of pipe, so that a 3″ pipe would cost 1½ cents per foot to dip.

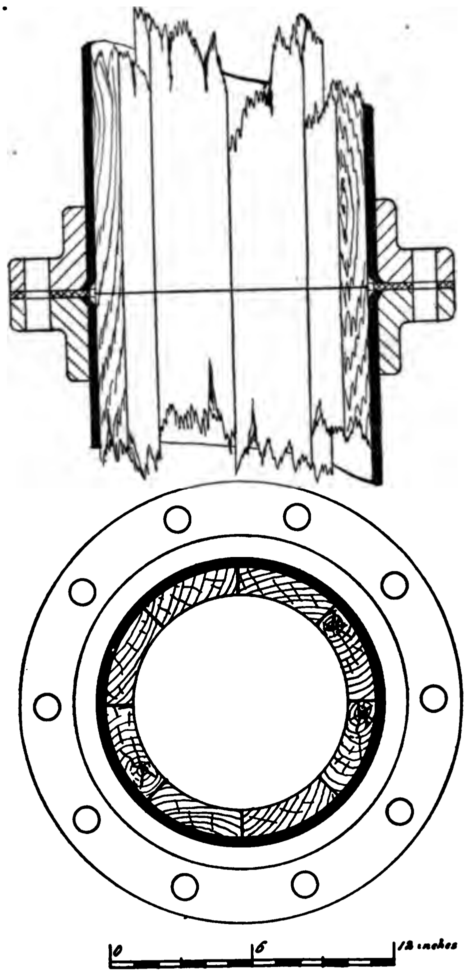


FIG. 26.

1.2.49. Where the water in the mine has a high temperature, as in the Comstock mines, coatings of the kind described are of no value in protecting the pipe. Galvanizing the pipes will protect against some waters. Some pipe manufacturers use an alloy consisting of lead, tin, and nickel, lead being the chief constitutent. This is a better coating than the zinc of the galvanized pipes, and also has the advantage that the pipes can be bent cold without cracking the coating. To bend galvanized pipes and not injure the coating, they should first be carefully heated to a moderate temperature.

1.2.50. Iron pipes have also been protected inside by wooden linings. At the New Guston Mine, Montrose, Colorado, the lining shown in Fig. 26 was used. The pipe in this case should be asphalted or painted with a protective coating before introducing the lining. Redwood is the best material for the latter. The staves should be cut off slightly longer

than the lengths of the pipe, so as to secure contact of the ends of the staves and also allow for the packing between the flanges. The pipes are necessarily larger for wooden linings, and this is perhaps the main objection to their more common use. A thin coating of cement has in some cases been a good protection.

1.2.51. In the greatest number of cases the best plan will be to use heavier pipe and protect it as well as possible by coatings.

1.2.52. *Air in Water-Pipes.* Frequently pumps take in a small amount of air on the suction-stroke, either by leakage or intentionally, in order to keep the air-chambers filled; and this air will accumulate not only in air-chambers, but also, when these are filled, at any high places along the discharge-pipe. Besides contracting the free passage of the water, such air is liable to be carried along in a body when the over-pressure necessary to force the water through the contracted space has become sufficiently great, and then to cause water-hammer by rising

FIG. 27.

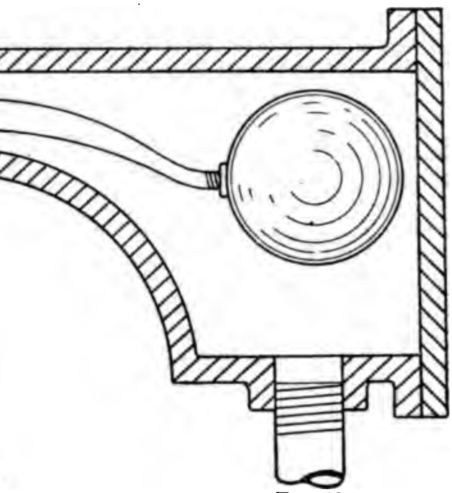


FIG. 28.

back through the descending pipe; or, if carried far enough, by entering the next rising part of the pipe, where it is in a position still more dangerous to the pipe. Therefore, wherever possible, discharge-pipes of pumps should rise all the way toward the discharge end, so that the air may be continuously expelled. Where this is not possible, it is necessary to use either some form of automatic air-valve, or a vertical pipe connected to the high part of the pipe-line (the vertical pipe rising to an elevation equal to the pressure-head at that point). A small adjustable opening or a cock, placed at the highest point to permit the air to escape with a small waste of water, would in some cases serve the same purpose. For all air-escapes it is necessary to have a pocket or chamber at the highest part of the pipe-line, to permit the air to accumulate, as it would, for the greater part, run past any small opening without being diverted into it. Automatic air-valves for letting accumulated air out of pipes must have sufficient weight in air to open the valve against the overpressure in the pipe. They must also be so constructed that they will close by the combined effect of buoyancy and the pressure due to the rush of water. Figs. 27 and 28 show air-valves of this type.

1.2.53. On many light pipe-lines, the main office of air-valves is to admit air to the pipe and prevent its collapse from atmospheric pressure when the pipe becomes emptied of water, and also to let out the air when the pipe is first filled with water. It is evident that such air-valves must be much larger than those previously described.

1.2.54. Fig. 29 shows a hollow ball air-valve suitable for light pressures. The air-

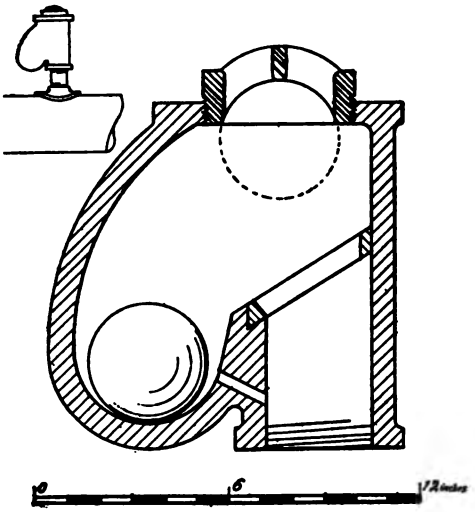


FIG. 29.

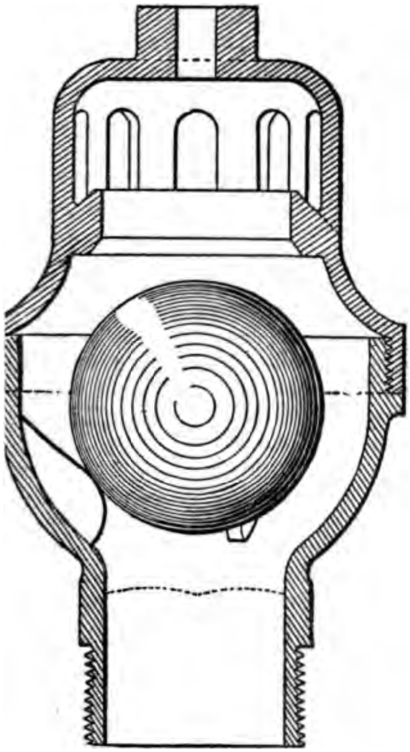


FIG. 30.

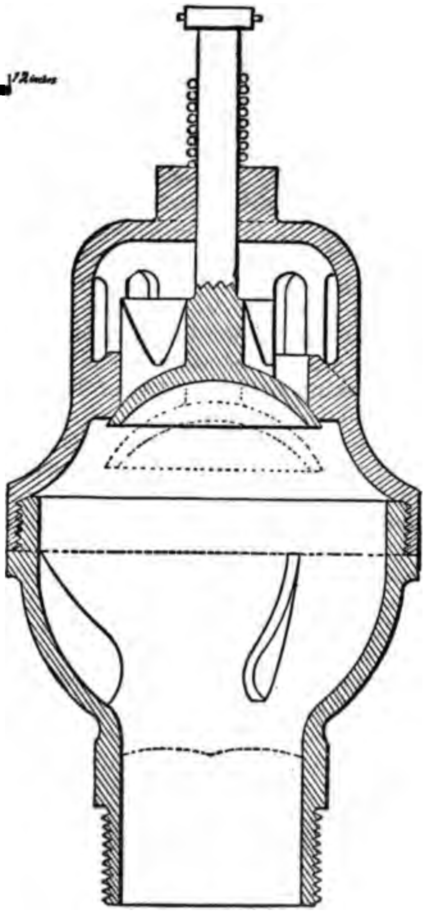


FIG. 31.

lve in Fig. 30 has a wooden ball covered with rubber, and is, there-
re, more rigid and not liable to be pressed out of shape and remain

stuck in its seat. For high pressures, the same make of valve is constructed with a bell-shaped metal valve, as in Fig. 31. The bell-shaped valve (Fig. 31) is closed by the rush of escaping water. In all the forms of ball valves, the ball is the valve and float in one. They do not operate to let air out of the pipe, unless the pressure falls very low, as in case of a break in the pipe or its emptying.

1.2.55. Besides the air taken in by pumps, there is always air contained in the water. It is not generally possible to predict under what pressure such air will be liberated from the water. It is, however, almost certain to be liberated if the pressure falls below that at which it has entered from the outside, where it was under atmospheric pressure.

1.2.56. Air is generally absorbed under pressure in an air-chamber, and such air will be released when the water which contains it reaches a high point at a lower pressure. Air will also be more readily released when the temperature increases, so that air may be looked for in the elevated parts of long pipe-lines which are exposed to the heat of the sun.

1.2.57. *Notes on Steam- and Air-Pipes.* In this class of pipes the first care next to safety and preventing leaks should be to keep as much of the heat in the steam or air as possible. It is advantageous, therefore, to locate such pipes in upcast shaft compartments. In the case of steam- and reheated-air-pipes further protection against radiation must be afforded by non-conducting coverings. The latter should in turn be protected from moisture in order to be efficient. This can often be done by wrapping the non-conducting material with tarred canvas. The pipe connections should not be covered, as leakage from them might enter the non-conductor, and they should also be accessible for repacking. It is a good plan to provide small conical rings at intervals, to act as "umbrellas" for shedding off the drip. These are best placed just below pipe connections, so as to carry off any leakage drip and prevent its soaking into the non-conductor.

1.2.58. Steam-pipes, and generally air-pipes, should be provided with traps at low points, for the purpose of draining off the condensed or entrained water, which must be prevented from getting into the motor cylinder of the pump engine, and which, besides contracting the passage at points where it accumulates, and thereby causing resistance to flow, is also liable to produce water-hammer and endanger the pipe. For this reason, as soon as a steam-pipe is shut off for a time, the drains should be opened to let out all the condensed water.

1.2.59. A break in a large steam-pipe underground is a serious matter. Where such an accident is liable to occur, as in some shafts in moving ground, provision should be made either to have the increased rush of steam automatically operate a self-closing device, or to connect a throttle at the surface, or valves at intervals, with a handrope passing down the shaft or other parts of the works containing the pipe.

1.2.60. Where steam or air is conducted a long distance to drive a reciprocating pumping-engine underground, it is best to connect the pipe to a receiver from which the engine takes its air or steam. The receiver, from which the engine draws intermittently, acts as an equalizer of pressure and flow in the pipe, so that a somewhat smaller pipe can be used with the receiver than without it, because the flow in the pipe is practically uniform.

1.2.61. It is better to use first-class gate-valves on steam- and air-

pipes as well as on water-pipes, as they cause less obstruction to the flow than globe valves, which, if used, should be so placed that water cannot accumulate in the globe. Tightness against leakage is important in steam- and air-pipes, for economical reasons. In long pipes the loss from leakage is often enormous. These should, therefore, be carefully designed and erected.

1.2.62. Steam- and air-pipes should have stop-valves, not only at the pump engine, but also at the boiler or air-receiver, so that the pipe can be repaired without shutting down the boiler or exhausting the receiver. Before connecting steam- or air-pipes to the engines to be operated through them, they should be thoroughly blown out to remove any loose scale or dirt which might afterwards get into the engine.

1.2.63. The heat generated by steam-pipes has a tendency to cause vapor to form, which rots the timbering of the mine.

1.2.64. *General Remarks.* All pipes (water, steam, or air) should be larger when their length. is great, to compensate for the additional resistance to flow.

1.2.65. Elbows and bends for the same reason should be formed to a large radius, where economy is desired and where space permits.

1.2.66. All shut-off valves and gates on water-pipes should be so arranged that they can only be closed slowly; then the water flowing in the pipe will be brought to rest gradually and without shock. The longer the pipe and the swifter the flow the more slowly should the gate or valve be closed.

1.2.67. Joints in pipes should be accessible. In underground workings they should stand some crowding out of line without leaking, and should remain in good condition for a long time.

1.2.68. It is of the greatest advantage to have as much as possible of the supporting arrangement for pipes, pumps, and rods in a shaft designed to be made of wrought-iron and timber, and the iron work of simple form, so that breaks can be quickly repaired by the mine blacksmith and carpenter. For large pumping-plants, a small machine shop is almost a necessity. Extra flanges for pipes, elbows, and other parts should be kept on hand.

1.2.69. If a line of pipe be properly designed and carefully put up at the start, much annoyance, repair work, and stoppage of machinery will be avoided, and the expenses of these in a year's run will almost more than equal the increased first cost.

CHAPTER III.

Pump-Valves.

1.3.01. *General Types.* Valves for pumps used in mines are of various types, their design and construction depending upon the conditions under which they are intended to operate. They may be divided roughly into hinged valves, commonly called clacks, which open by swinging about an axis parallel to the face of their seat; straight-lift valves, which rise evenly, and generally vertically, off their seats; and flexible valves, which alter their form on opening.

1.3.02. The pumps of the so-called Cornish system have usually hinged or clack valves, although single- and double-seated straight-lift valves are also often used, particularly in Europe.

1.3.03. In direct-driven pumps, straight-lift valves are almost entirely used. These are usually simple, often practically rigid, rubber disks, the seat being in the form of a grating. Flexible valves of rubber or leather are suitable only for very low lifts.

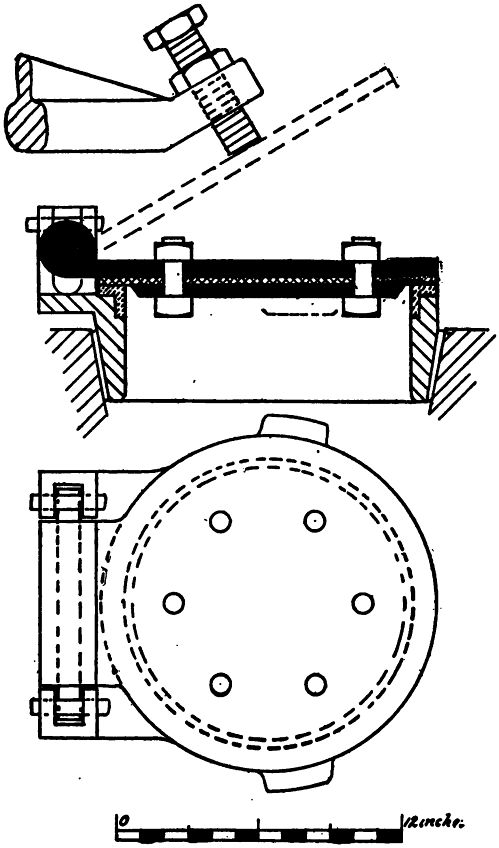


FIG. 32.

1.3.04. *Requirements.* The points to be aimed at in the design and construction of a pump-valve are:

First—It should close tightly against its seat, which latter is usually made so that it can be readily removed for the purpose of truing up and repairing. Tightness of valves and plungers or buckets is particularly required in a pump which has to raise water partly by suction, and where reduced inflow of water necessitates slow running of the pumps.

Second—It should open easily, and remain open with a minimum of overpressure on its lower side.

Third—It should, when open, present very little resistance to the flow, and divert the current as little as possible from a straight course.

Fourth—It should close as promptly as possible, immediately on the completion of the stroke, or when the forward motion of the water ceases, because, if the valve is still open during the commencement of the return-stroke, the water flows back and acquires a velocity which is suddenly checked with a blow by the closing of the valve. The blow is the more severe the more tardy the valve is in starting to close and the longer the column of water above it.

Fifth—It should be simple in construction and not liable to get out of order easily.

Sixth—It should be readily accessible for purposes of repair and interchange.

1.3.05. *Valves and Valve-Seats.* In mining pumps, which have nearly always to deal with water carrying sand in suspension, the tight

closing of the valve is, by this cause, often prevented. The valve-faces, or the whole valve, are usually made of some elastic material, so that any particles lodging on the seat will be pressed into the valve-face and not prevent its coming in contact with the metal seat, as would be the case if the valve-face were also of metal. When the water permits it, leather is much used for facing the valves. Where the water is very acid, rubber must be used. Hot water requires rubber-composition. This material has long been used for the disk-valves of direct-acting steam-pumps. It is said to have been first used for the faces of clack valves of Cornish pumps by Mr. Deidesheimer when Superintendent of the Hale and Norcross Mine, in Virginia City, Nevada. The composition disks are usually ⅝″ thick for clack valves. Fig. 32 shows a hinged clack of common form, with composition-rubber facing. When the valves are large and the water very hot, it is better to bore out the central portion of the disk in order to reduce liability of cracking from unequal expansion. Hinged valves are more liable to leak than straight-lift valves, as they generally wear unequally by striking first either at the edge nearest to or at the edge farthest from the hinge. When the hinges are made of metal the pins should be very loose, so that they will not become clogged and by their friction retard the valve. The leather faces of clack valves are often extended to serve as hinges for the valves, as in Fig. 33, which shows a double valve of this kind.

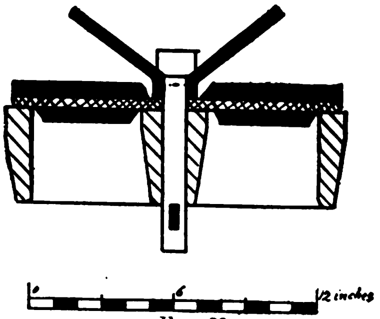


FIG. 33.

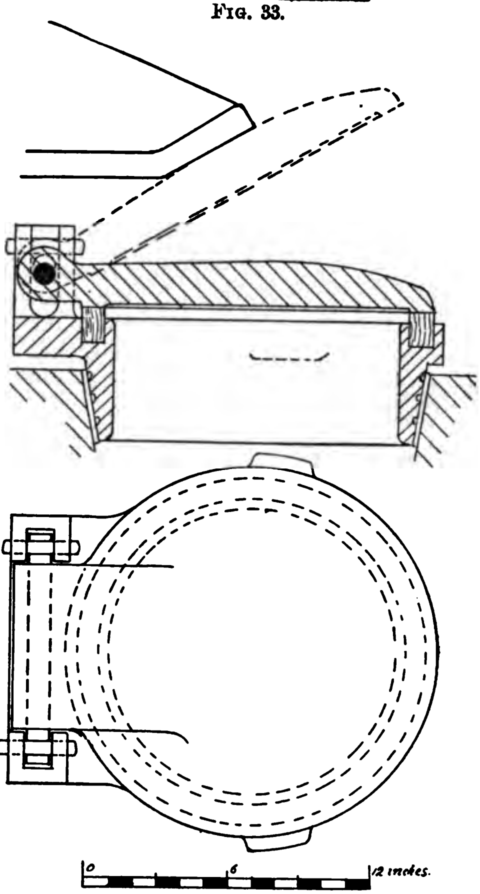


FIG. 34

1.3.06. For low heads and small pumps, such as are operated by men or animals, simple leather flaps, reinforced by a couple of washers held together by a bolt, are often used. Sometimes they are nailed to one side of a bored wooden block, which serves as a seat.

1.3.07. Boxwood, maple, beech, and even pine, have been used for valve-seats of metal-faced valves, and they are very durable, but always leak, as the grit in the water cuts out the soft part between the fibers of the wood, and this also retains particles of sand, which cut out the valve-face. The small blocks of wood are pressed into a groove in the valve-seat, the end of the grain being presented to the valve-face. Fig. 34 shows a hinged valve with its seat constructed in this manner.

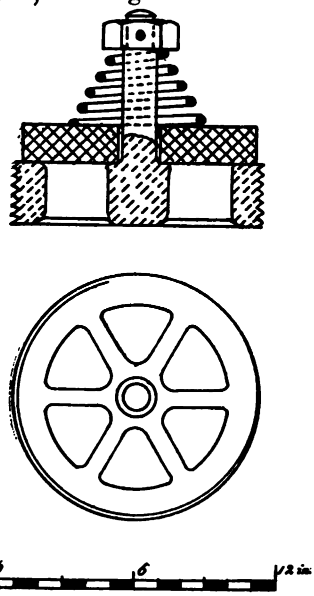


FIG. 35.

1.3.08. For valves with elastic faces, brass seats, or seats faced with brass, are advisable with acid water. The last Cornish pumps operated on the Comstock had brass-faced valve-seats, constructed as shown in Fig. 32.

1.3.09. Fig. 35 is a straight-lift valve like those used in direct-acting pumps. It is simply a thick rubber disk, supported, when closed, on a metal grating which forms the seat. For higher pressures the openings in the grating must be made very small, and rubber-composition used for the valve. Such valves have been used for pressures of 500 lbs. to the square inch, but for such pressures the valves are usually held in brass cages, as in Fig. 36. Straight-lift valves are also made of metal, with leather or rubber facing, as in Fig. 37.

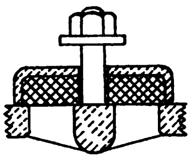


FIG. 36.

1.3.10. The guides of straight-lift valves must be arranged so that they will not cause friction or binding, and thereby retard the action of the valve. The width of the bearing of the valve on its seat must be such that the material will not be destroyed too rapidly by the repeated and more or less heavy blows on the closing of the valve. On the other hand, the bearings should not be too wide, otherwise greater overpressure will be required below the valve to open it. This overpressure is, however, not greater in the ratio of the areas exposed to pressures above and below the valve, because there is always a film of water between the valve-face and its seat, through which the pressure is transmitted, and to a considerable extent balanced.

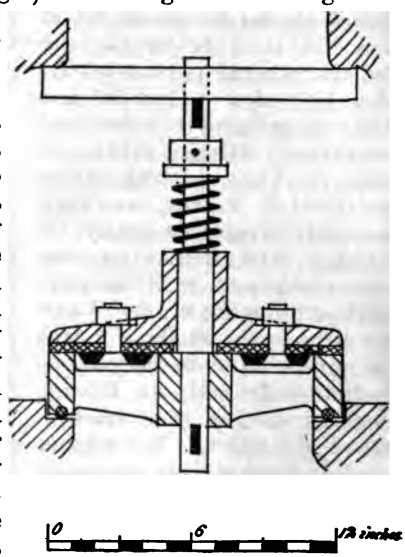


FIG. 37.

1.3.11. Often the water of a mine is corrosive in its action, or con-

nuch gritty material which cuts the valve-seats and valve-faces, ; great difficulty is experienced in finding a proper material or ıction by which the valves can be kept tight.

2. Flexible valves are generally made of rubber. They are suit- ıly for moderate lifts. Round and rectangular forms exist. Their orm a grating, which supports the rubber at many points. Fig. strates a type of round flexible valve, such as is used for air- of steam engines. The seats of all valves having flexible faces ıave all the sharp corners of the edges of the seat rounded off, so

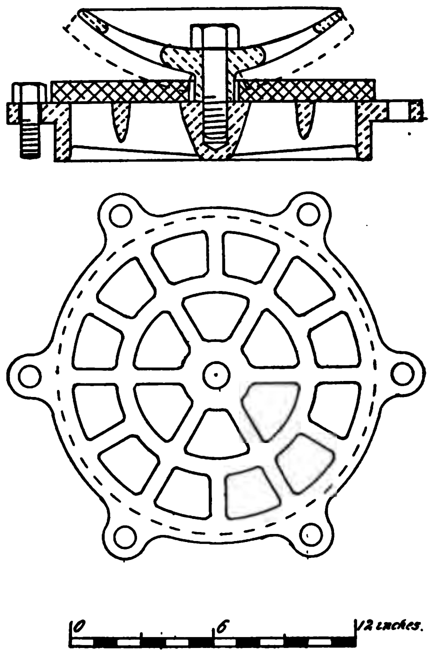


FIG. 38.

to cut the flexible material. Flexible valves open with very verpressure beneath them, because the least excess of pressure up the exposed part of the valve and lifts it a very little at the dge of the seat, where the water enters, and thus communicates ssure to a greater area, which is again increased, and the valve r rapidly peeled off its seat.

3. *Area and Lift of Valves.* Quick, easy opening and closing, minimum of obstruction to the current passing the valve, were ned before as requisites for all pump-valves. As it is generally le (for reasons stated farther on) to keep the lift of valves as ıs possible, it is necessary to make them of a correspondingly ırea, so as to keep down the velocity and consequent resistance flow past the valve. Such enlargement of area must, however, ; within limits, as the leakage is liable to be greater with larger when closed, and also because the valve, during its closing

stroke, permits some water to flow back, so that the decrease of this back-flow due to the lower lift and shorter time of closing is counteracted more or less by an increase due to the greater circumference exposed to back-flow. The higher the piston-speed of a pump, the greater should be the area of the valves, in order to insure small resistance as well as quick closing. Suction-valves should be of ample area in order to reduce the resistance, particularly where the suction-lift is considerable; also in high altitudes and where the water is warm.

1.3.14. In order to keep the diameter and also the lift of valves within bounds, straight-lift valves are quite often constructed with double or multiple seats, as in Figs. 39 and 40, the valves and seats being annular with inner and outer discharge-edges.

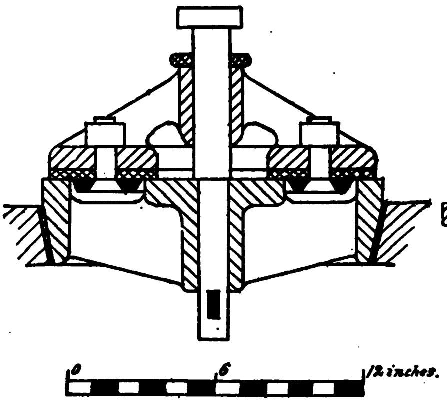


FIG. 39.

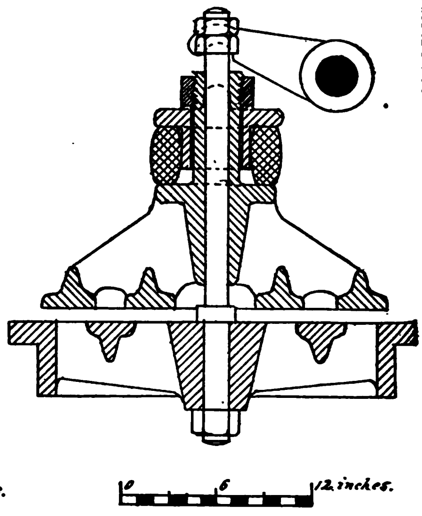


FIG. 40.

1.3.15. Where valves are placed in buckets, as in the ordinary lift and jackhead pumps, the valves can naturally not be made of the requisite area, and the resistance introduced by the contraction acts to reduce the speed at which such pumps may be operated. This defect is, however, to a great extent counteracted by the uniform direction in which the water moves, as it is not reversed in its course in this class of pumps. Such valved buckets will be described in the chapter on Cornish sinking-pumps. (See 2.3.27.)

1.3.16. *Action of Valves.* Both suction- and discharge-valves should open and close as nearly as possible coincident with the ends of the pump-stroke. Tardy closing produces back-flow and increased intensity of shock. Tardy opening of the suction-valves is due to their excessive resistance, and indicates that there is liability of a reduced fill of the pump for the suction-stroke, and a shock when the plunger or piston strikes the water on the return-stroke. Promptness of closing is particularly desirable for the discharge-valves where the head is great. A slightly reduced lift and increased resistance due to it in the discharge-

valve is not so great a detriment. Promptness of closing can be secured by making the valves heavy, or by using the pressure of springs. Stops must be used in all cases to keep the valve-lift between limits, and it is well to make these so that the extreme lift can be adjusted to suit the best working of the pump. Clack valves for Cornish plunger pumps, Fig. 34, are usually made heavy, of cast-iron, and the stops are cast on the clack-chamber doors. Sometimes spring-stops, which are compressed by the valve when the overpressure beneath holds it open, are used. Such springs also serve to accelerate the closing of the valve at that point where its weight is least effective. Fig. 41 shows such an arrangement, which was designed by Mr. S. N. Knight, of Sutter Creek, Cal. The closing of the rubber disk-valves commonly used in direct-acting steam-pumps is accelerated by springs. (Fig. 35.)

1.3.17. *Number of Beats of Valves.* The admissible number of beats per minute of a valve, and therefore the number of strokes of the pump,

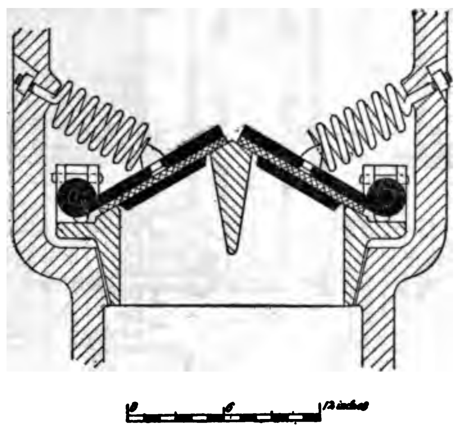


FIG. 41.

depends upon many conditions. Among these are: design, size, weight, and lift of the valve; length of the pump-stroke; velocity of flow at each part of the stroke; the head pumped against; length of the discharge-pipe; the height of suction-lift; and also whether a single pump does the work, or whether two or more, operating in rotation, force the water into the same pipe. All these conditions influence the motion of the valves to such an extent that they must all be considered and calculated or otherwise determined as far as possible, in order to decide at what rate a pump can be allowed to run under different conditions.

1.3.18. *Mechanically Actuated Valves.* A modern method of securing perfect action of pump-valves is to aid their movements by mechanical means, as in the pump valve-gear of Prof. Riedler, a form of which is shown in Fig. 42. The valve is here constructed so as to open as freely as possible without the assistance of mechanism. A little before the time when the valve should close entirely, and when the velocity of flow is already considerably reduced, so that a partial closing will offer no appreciable obstruction, a lever or rod operated by valve-gear from the

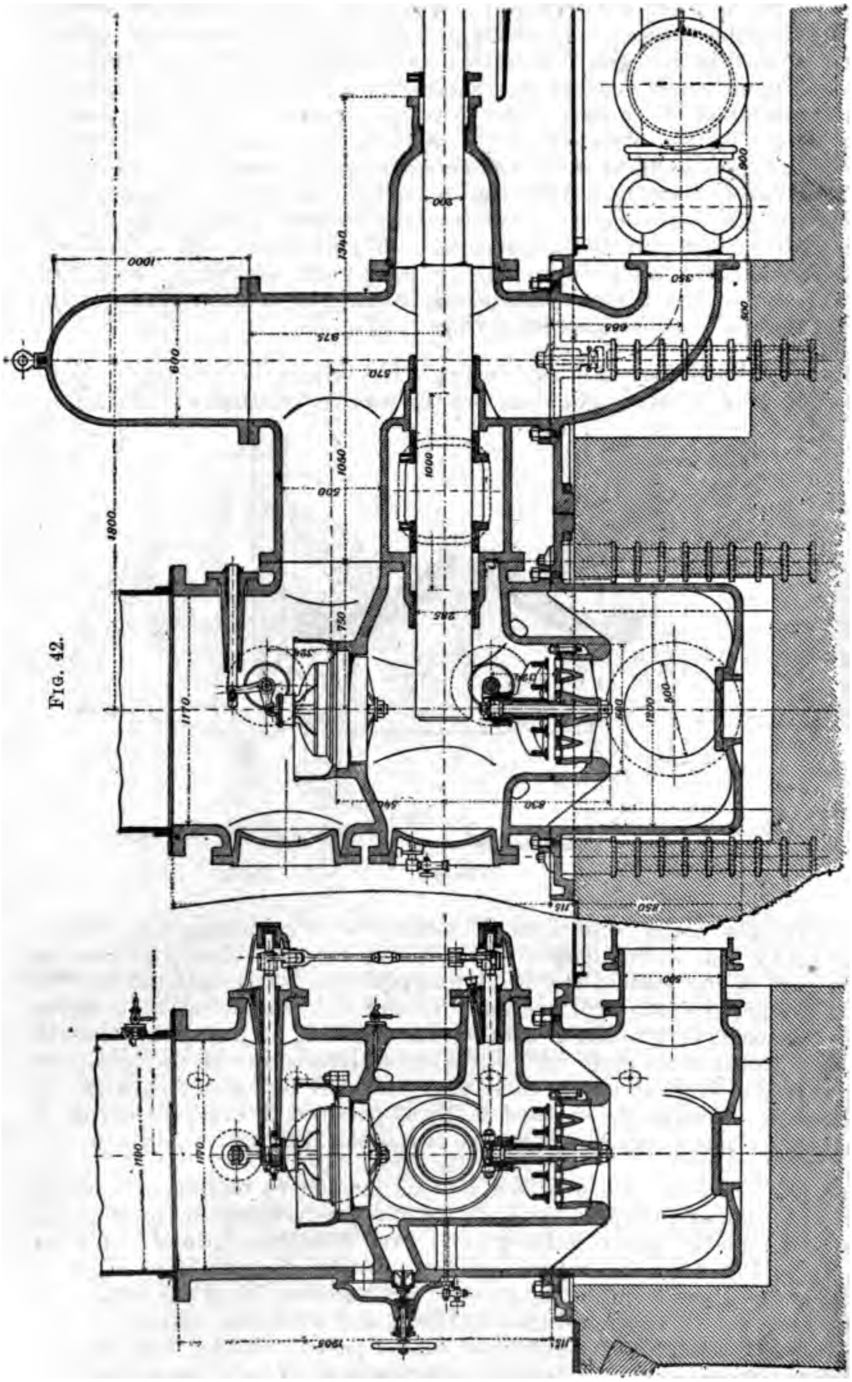


FIG. 42.

:-shaft moves toward and closes the valve; the arm then recedes, emoves all pressure from the valve before the time for its opening ɜs. With non-rotative pump-engines this arrangement is not appli-, but it is used successfully ;eam-pumps driven by ro-› engines. Riedler has ructed his pump valve-in various ways; some are ted by cams, others by trics; in some the closing ; are used to remove the ıre of a spring from the of the valve before its time ening; in others the lever ɿed with a spring; and still her constructions a small ıulic plunger is used in-of a spring.

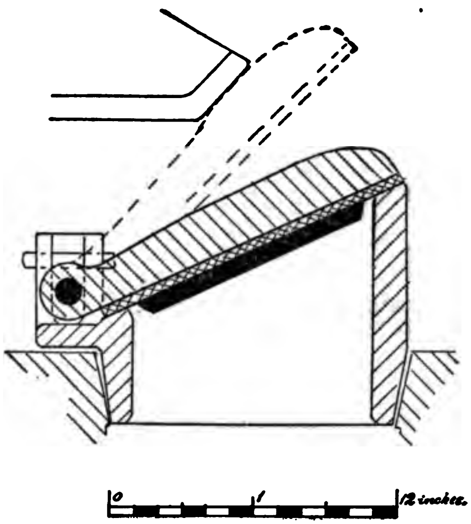


FIG. 43.

.19. *Inclined Valves.* Clack s with inclined seats, as ɑ in Figs. 41 and 43, permit ore direct path for the : than the type shown in 32, 33, and 34; but in ;al pumps the angle which the valve makes with a vertical line s for the wide-open position than for the valves with horizontal ; there is therefore less acceleration, tending to close the valve by its own weight, and the use of a spring at the back of the valve is indicated. When used in inclined or horizontal pumps, having the clack-chambers placed parallel to the pump, a single valve, inclined to the axis of the chamber so as to be more nearly horizontal, works very well, even without a spring, because the weight-acceleration tending to close the valve is greatest at its wide-open position. (Fig. 44.) Particles are not so liable to lodge on inclined valve-seats.

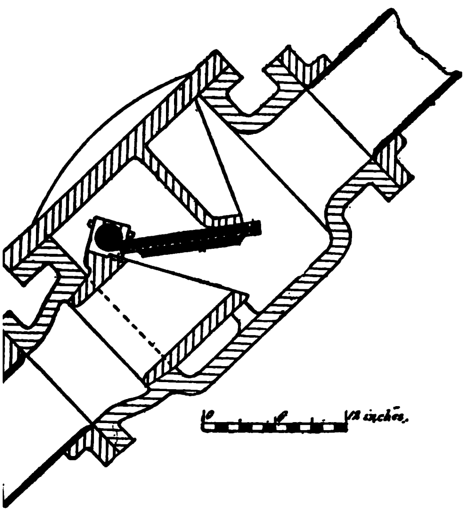


FIG. 44.

1.3.20. *Multiple Valves.* Several valves in a set are ently used. This is the usual method in large direct-acting steam-ɔs. In the Cornish system double valves, as in Figs. 33, 41, and 45, ɾten employed. The use of a number of smaller valves, instead of ırge one, is generally necessary for high pressures. Multiple valves

also present the opportunity of making the weight, lift, or spring-tension of the different valves unequal, so that they will seat successively and not all together, thereby causing a more gradual arrest of the water-column as it falls back, and thus more efficiently reducing the chance for blows than could be done by a single valve, unless the single valve is operated by mechanism, as in Riedler's construction. Fig. 46 shows a multiple valve of a type much used for waterworks pumps. Fig. 47

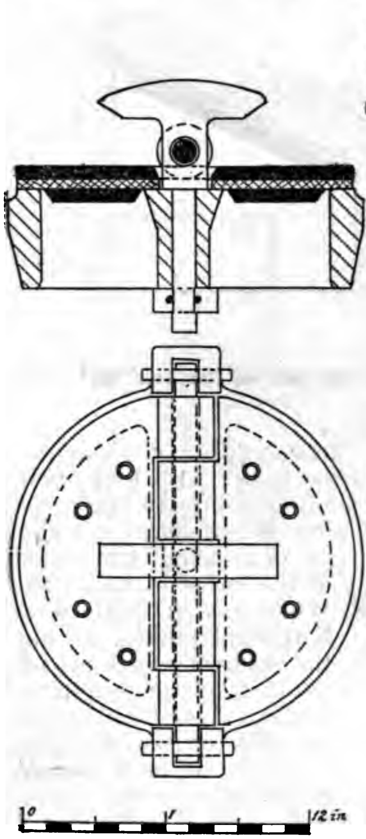


FIG. 45.

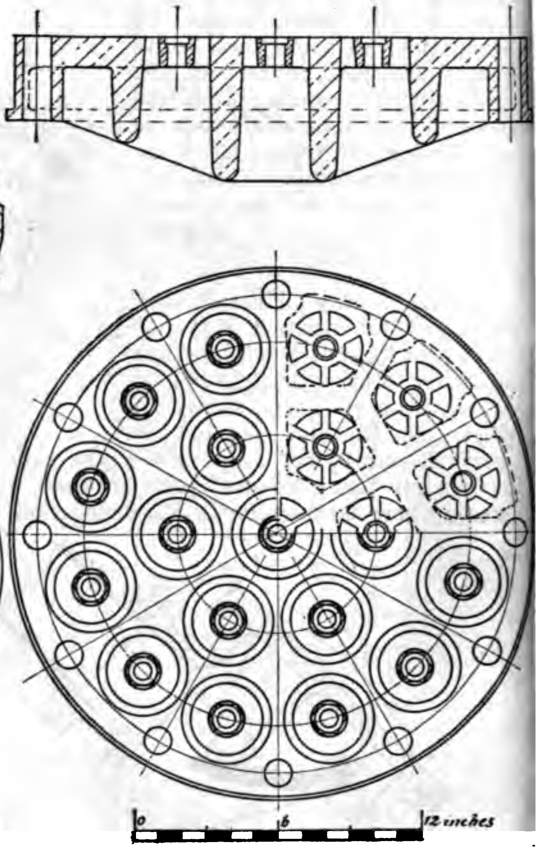


FIG. 46.

is a form of valve-support which permits of getting a large number of valves into a comparatively small valve-chamber.

1.3.21. *Spring-Loaded Valves.* If a valve be made heavy in order to assist in its rapid closing, its resistance to opening is increased, and such increase is twofold: first, the heavier valve must be balanced by a greater force beneath it; and, second, there must be an additional increase of force in order to move the greater mass of the valve into its full-open position in the same time that a lighter one would be moved. If, on the other hand, a spring, the mean tension of which is equal to the increased weight for which it is substituted, is used, there will be less resistance to moving the valve to its full-open position, and the valve

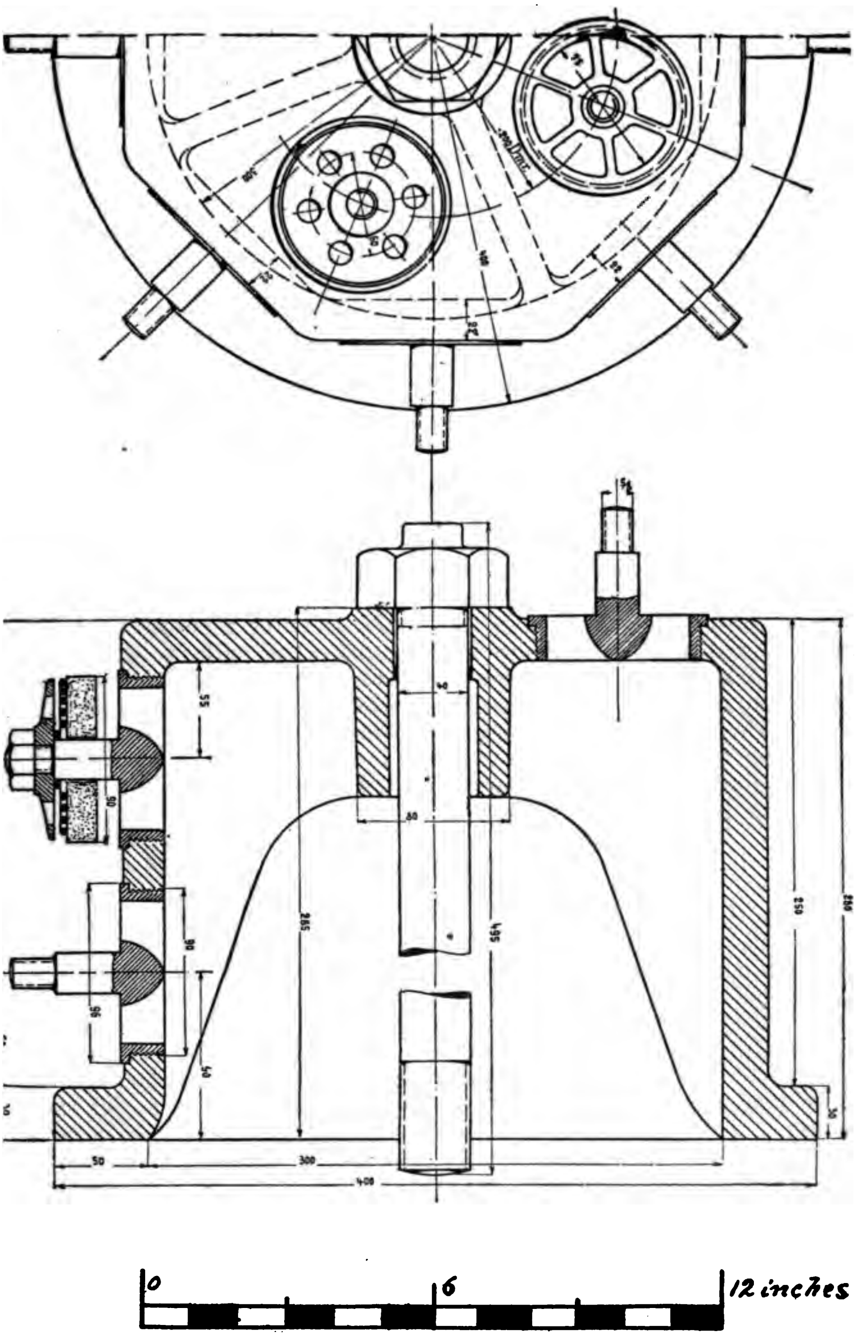


FIG. 47.

will also close more rapidly than by means of an equivalent weight, because, in the latter case, the increased weight or force has also to move an increased mass, while the same force exerted by a spring has less mass to move, and will, therefore, move it the same distance in less time. This argument shows that it is better to make the valve as light as is compatible with strength, and to accelerate closing by means of proper springs. The springs should be made adjustable in tension, and, to secure easy opening of the valve, they should not bear appreciably on the latter when closed. By using a number of smaller valves equivalent to one larger one, their aggregate mass can be less than that of the single one, because their thickness can be reduced with their area. A multiplicity of valves favors the application of springs, because these can be made light for small valves. Spring brass is the proper material for valve-springs, as steel would soon rust away and is also more liable to break from shocks. Springs are very extensively used for the rubber disk-valves of direct-acting pumps (Fig. 35). For pumps of the Cornish system, their application has been limited, but there seems to be no reason why, if properly constructed, their use should not be advantageous.

1.3.22. *Valve-Chambers and Valve-Seat Fastenings.* The seats of valves are usually separate from the valve-housings, or clack-chambers, and are held in place either by bolts, or simply by their own weight aided by the friction of a conical recess into which they are forced by the pressure of the water upon the valve when closed. For small valves, the seats are frequently secured by screwing them into the body of the chamber. Fig. 37 shows a single disk-valve with its seat secured by a central bolt. The suction-valves of Cornish lift pumps are now, less often than formerly, arranged for drawing up through the column-pipe. This arrangement is advantageous only where a shallow mine, involving the use of only a single lift, is drowned out, or where a deep mine is liable to be flooded up to, but not above, the level of the next higher set of pumps.

1.3.23. The clack or valve-seats of Cornish pumps are usually formed with a tapering ring or spigot, which fits into a boring of the clack-chamber. The spigot is wrapped with canvas, or similar material, before putting in place. If this is not done, the seat may jam so tight, or rust fast in the conical bore, that it cannot be got out without risk of breaking. The projecting part of the seat should have lugs cast on at opposite sides so that a bar can be inserted under them, and the seat pried up. Fig. 48 shows a common form of clack-seat in its chamber. For inclined pumps having also inclined clack-chambers, it is well to have some additional bolt-fastening for the valve-seat, as the latter has little tendency to fall back into its place, if by accident forced therefrom.

1.3.24. In order to gain access to the valves of pumps, the chambers are provided with doors or covers held in place by bolts. Fig. 48 is the clack-chamber of a Cornish plunger pump; the bolts for securing the door are hinged to the chamber-casting by an eye on one end, and fit into slits extending from the edge of the flanges. This arrangement has the advantage that the cover can be removed very rapidly by simply slacking the nuts sufficiently to permit the swinging aside of the bolts, and also that the nuts cannot be lost easily, or fall down the shaft, to the peril of men working below. In a shaft there should be the fewest

possible number of loose pieces or tools placed where there may be danger of their falling.

1.3.25. The covers of large valve-chambers are heavy, and the doors must be cast with lugs, and have a ring by which to lift them, and they should have starting-bolts to break the joint when it is necessary to take them off.

1.3.26. In order to compensate, in part, for the weakness of the chamber, due to having an opening in one side, it is well to have the

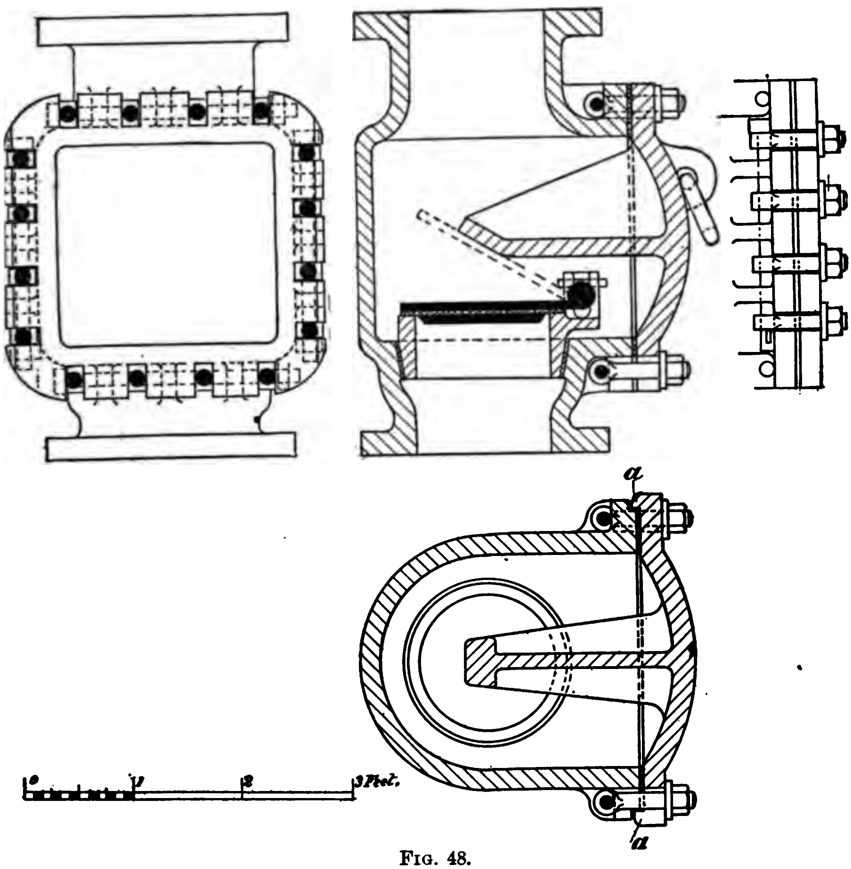


FIG. 48.

covers formed with a projecting ledge at the two vertical edges, which are fitted over the outer edges of the flange on the chamber, and serve to bind them together, as at a, Fig. 48. The doors of valve-chambers should be placed so that they are readily accessible, as the valves usually require frequent changing or repairs. Besides the large, heavy door for the removal of the valves, it is sometimes an advantage to have another small door on the side or in the main door, which can be quickly removed, and which is just sufficiently large to admit of inspection when anything is wrong with the valve, such as chips or gravel on the seat, which can be removed by the hand.

1.3.27. In horizontal pumps the valve-chamber covers are often on top, and admit of easy access to the valves.

1.3.28. *Stop-Valves.* In order to get at the discharge-valves of pumps, without draining the entire column-pipe above, a gate-valve is sometimes placed above the valve-chamber, which can be closed when it is necessary to get at the discharge-valve. The ordinary gate-valves in the market are generally of too light construction to bear the weight of the column-pipe, and also the lateral strains that are liable to be thrown on their casings. Special, heavy valves should be used for this purpose. A very good plan with Cornish pumps is to put above the discharge-clack an additional clack, which remains open and inoperative during the working of the pump, and swings entirely out of the way so as not to obstruct the flow. The valve must be arranged so that it can be closed by a handle from the outside, which is done without a shock when the pump is stopped. If the water be let out of the column-pipe, the pump-work will usually be out of balance on starting up again until the column-pipe is filled.

1.3.29. *Spare Gear.* In order to avoid delays, there should always be a number of valves and seats on hand, and ready to immediately replace others taken out. The number of parts necessary to be kept on hand can be reduced by having the valves, or at least such parts that cannot be made or repaired at the mine, of the same pattern so that they will be interchangeable.

SECTION II.

PUMP SYSTEMS OPERATED BY RODS.

CHAPTER I.

General Description of System.

2.1.01. Notwithstanding the fact that other more recently developed methods of transmitting power to operate pumps underground, such as direct steam, compressed air, water pressure, and, to some extent, electricity, are in most instances, particularly for great depths, more suitable and economical, the method of operating pumps in shafts by means of rods has still a considerable range of application for moderate depths.

2.1.02. The name "Cornish System" applies to an arrangement whereby a rod simultaneously operates a series of pumps, all of which are plungers, except the lowest, which is a lift pump. Each pump delivers the water into a tank, from which the next higher pump draws its supply. This system is said to have been first applied in 1801 by Captain Lean at one of the mines of Cornwall. The reason for using plungers is, that these, where they are not required to operate under water, can run uninterruptedly for a much longer time than lift pumps. Where submersion is liable to occur it requires a pump which can be operated and repaired under such conditions, and for that reason the older lift pump was retained as the lowest of the series. The kind of power used to operate the rods may be either steam or water. Originally the only method of working the rod was by means of a single-cylinder, single-acting engine, which lifted the rod and the water in the lift pump, and then allowed the rod to sink back, its weight driving down the plungers. The single cylinder of this Cornish engine did not admit of an economical degree of expansion of the steam, because the excess of pressure at the beginning of the up-stroke produced excessive strains in the pumprod and effected too great an acceleration of it and its attachments, causing shocks and frequent breakdowns. The introduction of compound, or Wolf, engines secured a higher and more economical rate of expansion with less variation in the extremes of pressure. These engines were, however, still single-acting, and therefore of large size in proportion to the work. Double-acting, non-rotative engines were introduced about the latter part of the "sixties." Later, double-acting, rotative engines, with crank and flywheel, came into use. A defect of this kind of direct-coupled, rotative engine is, that it cannot be operated at very slow speed, as it may then stop on the center, and it is therefore not suitable for the same variability of pump-work as the non-rotative engine, which operates for any length of pause between the strokes. Kley, of Bonn, remedies this defect of ordinary rotative engines by arranging the valve-gear so that the engines can rotate in either direction, and therefore they can be reversed auto-

matically before the end of stroke for slow speed, and in that case be operated similarly to non-rotative engines, while at a greater speed they turn the centers and rotate the crank in one direction. A recent arrangement of rotative pumping-engine is that of Regnier, in which the dead points are overcome by a smaller engine coupled to a crank at right angles to the main crank. These engines require only a comparatively light flywheel. They are, at present, the most perfect rotative engines for working pumps through rods, and a number of them are operating at mines in Germany.

2.1.03. Ordinary steam engines, geared to a crank operating the pumprod through a bob or beam, form one of the oldest applications of the rotative principle, and are much used on this coast. Probably the largest examples of this type are found on the Comstock. The geared arrangement is also the one suited to driving Cornish pumps by water-wheels. Reciprocating hydraulic-pressure engines began to be used for operating pumps about the middle of last century. Many examples of this class of engines exist in Germany, France, and England. On this coast, Mr. S. N. Knight, of Sutter Creek, Amador County, has been prominent in introducing a type of his own design.

2.1.04. In all double-acting arrangements for operating Cornish pumps by engines or other motors, part of the work is done on the up- and part on the down-stroke. For rotative engines and motors the work on the up- and down-stroke should be approximately equal. On the down-stroke the main work of pumping is accomplished by the plungers, while on the up-stroke the weight of the pumprod is lifted with the water in the lift-pump column. It is evident, since the weight of the rod aids the plungers in lifting their water, that, if the weight of the pumprods, plus half the total pressure on the lift-pump-bucket, equals half the total pressure on all the plungers, the work on both strokes will be equal. Unless balance-bobs are used, this leads to a very light pumprod, which, in order to be sufficiently strong to resist compression, must be made of iron girders, channels, or tubes. Such pumprods are expensive, and the connection of the sections presents difficulties and requires first-class workmanship. Pumprods are usually made of wood in this country, where there is an abundance of excellent timber. In order to secure proper strength, wooden rods require to be heavier than iron ones, for which reason they have to be equipped with balance-bobs, so as to equalize the resistance on the up- and down-strokes. Wooden rods, with balance-bobs, are almost invariably used where the Cornish system is applied on this coast. The maximum stroke used with Cornish pumps is about 10′.

2.1.05. A system allied to the pumprod system (inasmuch as the same kind of engines are used as motors, and the water raised by successive lifts) is that in which the column-pipe is made to serve as the pumprod, thereby saving some room in the shaft.

2.1.06. Owing to the weight of the pumprod, which has to be balanced, there is little virtue in double-acting Cornish pumps. A double-acting pump might be warranted only where a large quantity of water is to be raised from a depth of a few hundred feet.

2.1.07. Most of the proposed double-acting constructions have opposite plungers, one stuffing-box being a hanging one, and therefore exposed to all the sand and mud contained in the water. The only double-acting pumprod system which, in the opinion of the writer, has

any merit, and which also has found some application in Europe, is the Rittinger telescope-pump system, in which the column-pipe, like that mentioned in 2.1.05, serves the purpose of the pumprod. Such systems are, however, too complicated, and the pumps too inaccessible for our purposes here, and the writer knows of no case of their application.

2.1.08. The pumprod system has been used for depths of over 3,000′, but it is unquestionably unsuited for economical work under such extreme conditions. On account of the elasticity of the pumprod, the lower pumps do not get their full stroke, and their action at the end of the stroke becomes uncertain.

CHAPTER II.

Pumprods.

2.2.01. *General Arrangement.* The pumprods which serve to transmit motion from the engine or other motor to pumps of the Cornish system, were formerly sometimes several thousand feet long. Owing to the elasticity of the rods, referred to at the conclusion of the preceding chapter, and their great mass, both of which affect the working of the pumps and produce severe strains and frequent breakages at speeds that would be admissible with shorter rods, the working-speed of such long rods must be kept very low, and the pumps and entire working-plant must be larger for the same capacity.* The Cornish system should properly, therefore, not be applied for such depths, particularly as other methods of transmission are to-day available to give equal commercial efficiency.

2.2.02. Pumprods are composed of pieces or sections joined at their ends by very strong connections, which must be capable of bearing the continual reversal of heavy strains to which they are subject. The rods must be securely guided in the direction of their motion in the shaft or incline. As constructed in this country, they generally require to be arranged with counterweights to balance the excess of weight over that required to equalize the work on the up- and down-strokes. The plungers and sinking-pump rods are usually attached to the side of the main rod. In Europe, the main rod is frequently forked or made double to enable a single line of plungers to be placed in the axis of the rod.

2.2.03. Even where the sinking of a shaft has been completed, the sinking-pump often remains in place, no pump-station being put in at the bottom, where it might be flooded.

2.2.04. In order to enable sinking to be carried on easily, the sinking-pump rods must be capable of being readily disconnected and hauled up with the bucket of the pump. For this reason the sinking-rod is usually not in line with the main rod, but offset to one side and clamped to it, or to an intermediate distance-piece, in such a manner that it can be let down to suit the increasing depth.†

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*At the Combination Shaft, Virginia City, Nevada, a vertical pumprod, 15″ square and over 3,000′ feet long, operated a double line of 15″ plunger pumps, at a maximum of 6½ strokes per minute, the stroke being about 7′ 6″ at the surface.

†When Cornish pumps were still in operation on the Comstock, the sinking lift-pump was discarded in several mines and a direct-acting steam sinking-pump of the Blake, Knowles, or Dow type was employed.

2.2.05. *Material of Rods.* Pumprods are made either of iron or wood. The sections of the latter are usually connected by iron strapping-plates, though wooden plates are also used. Owing to the excellent quality of the timber, and the long pieces of it which can be obtained free from blemishes, wooden main pumprods are almost exclusively used on this coast. Iron pumprods of hollow rectangular cross-section, as in Fig. 49, are lighter than the wooden ones, and if properly designed and constructed, no balance-bobs or other counterbalancing devices will be required with them, so that the extra cost of such a rod might be compensated for by the saving in cost of balance-bobs and their stations. The moving mass being much reduced, not only by the lesser weight of rod, but also by the absence of counterweights, higher speeds and greater depths are admissible by the use of iron rods. Tubular iron rods can be made still lighter than those composed of I-beams.

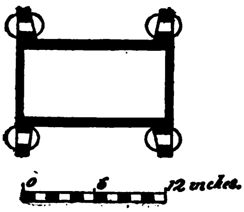


FIG. 49.

2.2.06. Iron rods require very careful workmanship, especially in the connections, which have to be very strong and rigid. Moreover, the exact length of pumprod sections cannot always be determined long in advance, and while wooden rod sections have the advantage that they can be cut to length conveniently, iron rods require careful and costly machinist work to effect such changes.

2.2.07. The only instance of a hollow iron main pumprod known to the writer on this coast is one at the Grand Central Mine (Arizona). This rod gave out in a very short time by becoming loose in the joints. Sinking-rods of iron, of solid section, are, however, extensively used, because, being only subjected to tension, they are better adapted to lift-pump work than wooden rods. They are also cheaper, consisting simply of solid rods with ends suitable for connecting by keys or other fastenings.

2.2.08. Wooden pumprods are usually of square section, except where two connected rods work a single line of plungers between them, in which case they are oblong in section. The so-called Oregon pine (Douglas fir, or *Pseudotsuga Douglasii*) is the best material for wooden pumprods.

2.2.09. Data relating to this wood were published in the 10th Census of the United States Government, of 1880, at Washington, containing the Report on the Forest Trees of North America, by Charles A. Sargent, Professor of Agriculture at Harvard College; pages 255, 259, 264, 410, 412, 476, 478.* Experiments for determining the tensile, compressive, and shearing strength of Oregon pine were also made by Arthur Brown for the Southern Pacific Co., by W. A. Grondahl for the Oregon & California Railroad Co., and by Prof. F. Soulé, of the State University, Berkeley, Cal.

2.2.10. All the experiments confirm the excellent qualities of the timber, but they also show that its resistance to longitudinal shear, or sliding of the fibers upon each other, is very slight. This fact must be taken account of in constructions, and such connections as hook-splices, and similar fastenings depending upon the resistance to longitudinal shear, should be avoided with this material. The following table, taken

*A very excellent pamphlet, giving the important results of some of the experiments mentioned, has been published by the Pacific Pine Lumber Co. of San Francisco.

from a paper read by Prof. Soulé before the Technical Society of the Pacific Coast, shows the results of different experimenters:

TABLE II.

Tests of Oregon Pine (Douglas Fir—Pseudotsuga Douglasii).

	University of California.	United States Government, Watertown.	Arthur Brown, for S. P. Co.	W. A. Grondahl, for Or. & Cal. R. R.
Ultimate crushing strength	5,055	8,496	6,000	------
Parallel to grain	------ ------	10,685 5,772	------ ------	------ ------
Ultimate shearing strength, parallel to grain	635 ------	442 356	600 ------	689 ------
Ultimate tensile strength	------	13,810	15,900	16,600

2.2.11. The pieces selected for rods must be straight-grained and as free from knots as possible. Pieces 16″ square and 70′ long were obtained of the requisite quality for the pumping-plant of the Ontario Mine, Park City, Utah. Sections of such length are transported by rail on two flat cars, being supported on swivel frames placed on each car.

2.2.12. *Lengths of Pumprod Sections.* The sections of pumprods should be chosen as long as they can be conveniently handled, because the number of connections is then reduced and more free rod-length available for attachment of pumps or balance-bobs. The long strapping-plates often required for wooden rods generally necessitate considerable length of the sections.

2.2.13. The admissible length of pumprod sections for vertical shafts is sometimes, however, limited by the height of gallows-frames or buildings, which do not permit raising the rods vertically prior to lowering them down the shaft.

2.2.14. *Connections of Wooden Main Pumprod Sections.* The iron strapping-plates generally used for connecting the sections of wooden main pumprods are usually four in number, and are frequently over 30′ in length. The 16″ pumprod at the Ontario Mine, previously referred to, had strapping-plates 33′ long of 1″x 10″ iron. Two opposite strapping-plates are secured to the sections by bolts passing through the wood. The bolts are usually square in section where they pass through the wood and through the plate under the bolt-head. The bolts should be sufficiently numerous so that the plates will hold to the rods by friction, independent of the shearing resistance of the bolts. It is, however, generally customary to utilize also the strength of the bolts of one pair of plates by driving hard-wood keys between the square ends of the rod sections after two plates have been bolted in place, because the plates are liable to become loose through shrinkage of the wood. The keys are then sawed off and the other pair of plates put on. The bolt-holes for these in one of the sections have then to be bored in the shaft. Where an entire new line of rod is put in, it is well to permit it to hang, if the time can be spared, after one pair of plates have been put on each joint. This permits the rod to straighten by its own weight, and stretches the

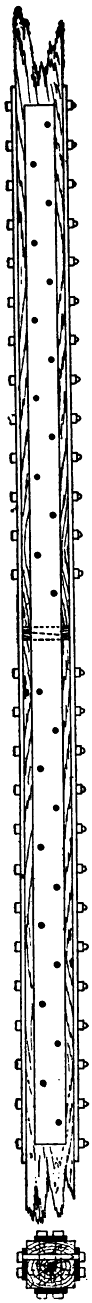


Fig. 50.

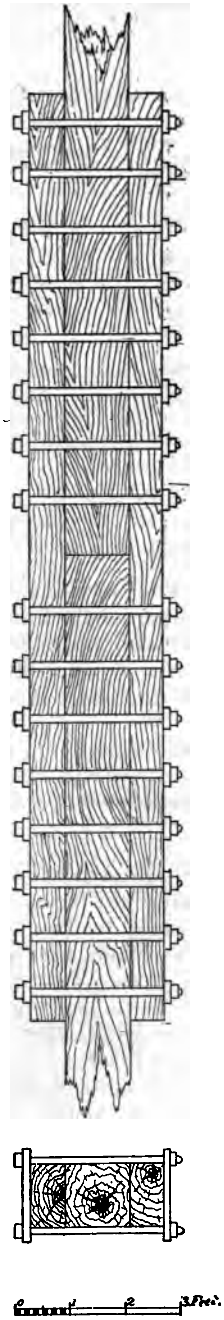


Fig. 51.

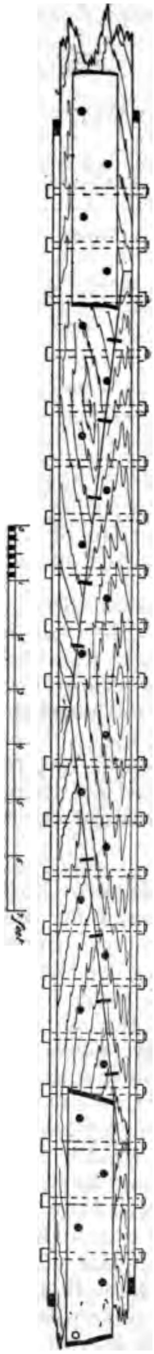


Fig. 52.

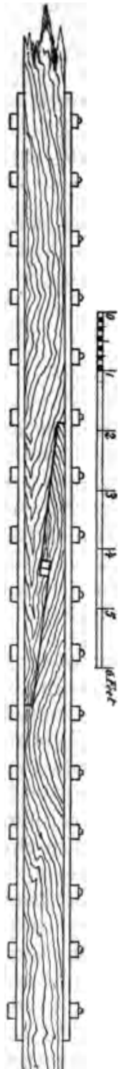


Fig. 53.

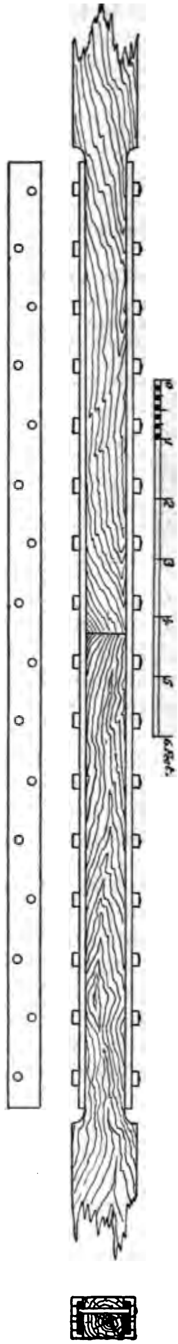


Fig. 54.

joints so that the keys can be driven home with better effect. The keys between the ends of rod sections are sometimes omitted. Fig. 50 shows a usual form of connection. The hook-splices sometimes used to additionally connect the ends of the rods, cannot add much to the strength of the joints. Where only one pair of strapping-plates is used on a rod, they are more liable to split through the line of bolt-holes. For this reason, also, the bolt-holes in the plates are not all in one line, but are placed in zigzag order.

2.2.15. Wooden strapping-plates, as in Fig. 51, are also occasionally used. As the plates hold the rod by friction, it is simpler to clamp the plates to the rod, and then also the rod and plates will not split through bolt-holes. Wooden strapping-plates have a better hold on the rod, because the coefficient of friction between wood and wood is greater than between iron and wood. The only trouble with wooden plates is the shrinkage of the wood, which loosens the clamp-bolts, and therefore these require frequent screwing up. Wooden strapping-plates, being of the same material as the rod, contract or shrink and expand equally with the latter, while iron plates are liable to severe strains, their expansion being different from that of the wooden rod. An objection to wooden strapping-plates is the space they occupy in the shaft, as they are naturally much thicker than iron plates.

2.2.16. Additional strength of joints is sometimes aimed at by overlapping the ends of the rods under the strapping-plates by a separate piece holding the rod ends by means of steel keys, as in Fig. 52. Such a connection was used at the Ontario Mine, previously referred to.

2.2.17. Main pumprods of iron or steel are generally so constructed that the joints in the different lines of channels, I-beams, or plates composing the rod shall alternate or break joints, so that no two joints fall at the same cross-section. The joints are secured by short strapping-plates held to the sections by tapered steel bolts well fitted into the straps and rod irons. The ends of the beams and plates composing the rod should be planed true. Keys of steel running through the rod and strapping-plates serve to bring the sections hard together, so that the tapered bolts can be inserted and screwed up. It is important that the workmanship of the joints of iron and steel rods be perfect, otherwise they will get loose.

2.2.18. *Connections of Sinking-Pump Rods.* Where wooden sinking-pump rods are used, they are often connected by hook-splices and one pair of iron strapping-plates, as in Fig. 53. The connection shown is objectionable, not only on account of the hook-splice, but also for operating inside of the sinking-column, because the projecting nuts and bolt-heads wear against the inside of the pipe.

2.2.19. By making the rods of oblong section greater than needed, the strapping-plates can be let into the wood deep enough to keep the nuts and bolt ends below the surface of the wood, and thereby prevent their wearing on the pipe. (Fig. 54.)

2.2.20. Iron pumprods of round or square sections are much used for lift pumps. Being always in tension, the joints are not so liable to get loose as with main pumprods. Fig. 55 shows a form of connection, the end of one section being fitted and keyed into a socket formed on the other section. A split pin through the projecting smaller end of the

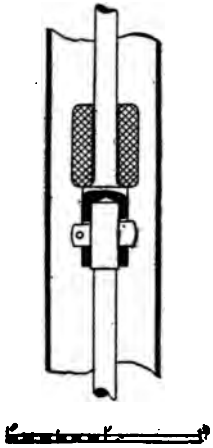


FIG. 55.

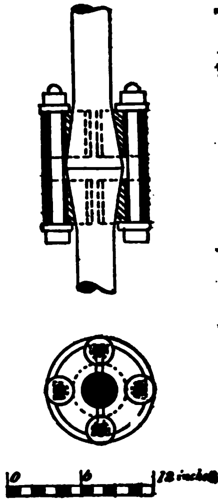


FIG. 56.

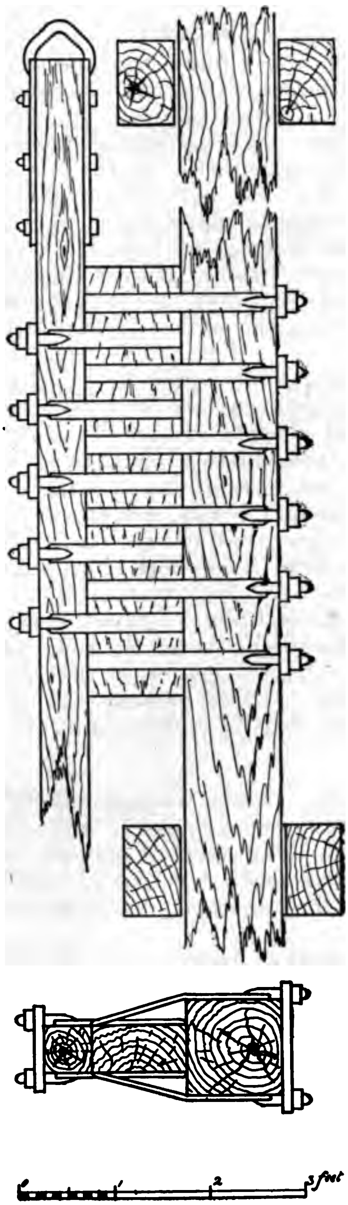


FIG. 57.

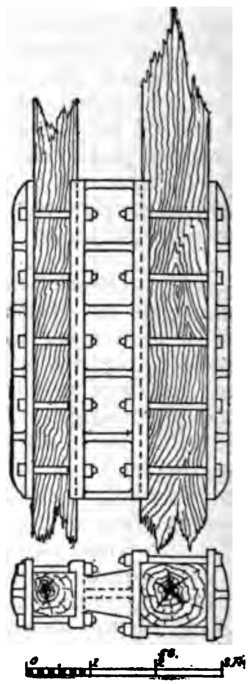
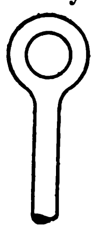


FIG. 58.

key prevents it getting loose. Fig. 56 illustrates a sinking-rod joint much used in Germany. The ends of both sections are upset, as shown, and fit into the cast-iron sleeve *a*, which is halved on a plane through its axis so that it can be put over the upset ends. A wrought-iron ring *b* holds the halves of *a* together, and bolts *c c* keep *b* in place. The swelled or upset ends of the rods are shown tapering, but they can also be made cylindrical in form to fit into a corresponding recess in the halved cast sleeve.

2.2.21. In order to prevent the projecting parts of iron sinking-rods from wearing against the inside of the column-pipe, rubber hubs or bosses (Fig. 55), extending in diameter beyond any of the projections on the rod, are often used. They are mounted loosely on the rod which they surround, so that they can lag behind the rod in its motion, and thereby distribute the fluid resistance of the passing liquid over the up- and down-strokes. Their cross-section can be as large as half the clear area of the sinking-column.



2.2.22. *Connections of Sinking-Rods to Main Rods.* The usual disposition of sinking-rods in relation to main rods was described in 2.2.04. The manner of offsetting and clamping the sinking-rod can be carried out in various ways. Wooden sinking-rods are often clamped to a wooden block or distance-piece, which is also secured by clamps or bolts to the main rod, as shown by Fig. 57. Clamping the two rods by one set of clamps, with the block between the rods, is a bad plan, as the shrinkage of so thick a body of wood is more liable to loosen the clamps. For this reason it is still better to use a cast-iron distance-piece, like Fig. 58, between the rods. Fig. 59 shows a distance-piece for a round iron sinking-rod. Where a sinking-rod is connected to the main rod, guides should be placed as near as possible above and below the connection.

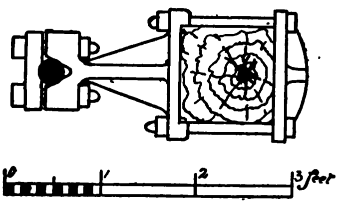


FIG. 59.

2.2.23. *Preservation of Pumprods.* The iron-work of pumprods must be protected against rust, particularly the joints and the inside of hollow iron pumprods. Hauer recommends pickling in acid to remove rust, then coating with warm oil, and finally painting with red lead.

2.2.24. The rusting of iron strapping-plates and bolts has a tendency to rot the wood in contact with them.

2.2.25. Wooden rods last better if planed and painted, as the water runs off more readily. The abutting ends of wooden rods should always be well painted with thick paint, as this is where rotting usually first commences.

2.2.26. *Connections to Motive Power.* Wooden pumprods, where operated, as is usually the case, from a beam or bob, are generally coupled directly to the pin in the bob-nose, without an intermediate connecting-rod or link. The upper end of a rod so coupled necessarily sways back and forth during each stroke by an amount equal to half

the amount of curvature of the arc described by the bob-pin. The top of such a wooden pumprod is fitted with brass boxes for taking hold of the bob-pin. The boxes are firmly held to the rod by heavy strapping-plates, as shown in Fig. 60, which is the usual form of top-connection; Fig. 61 illustrates a connection for extra heavy work.

2.2.27. Iron main pumprods are too stiff to admit of the manner of connection just described. They are therefore guided in a straight line at their upper end, and connected to the beam or bob-nose by a link or connecting-rod.

2.2.28. *Catches and Bumpers; Stops.* In order to catch the rod in case of its rupture, and prevent it from breaking pumps and other more valuable machinery in the shaft, it is customary to attach projecting catches to the rod, which strike, when the rod breaks, on

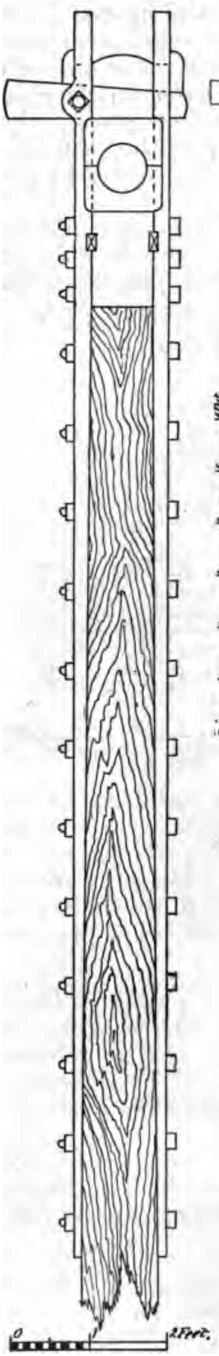


FIG. 60.

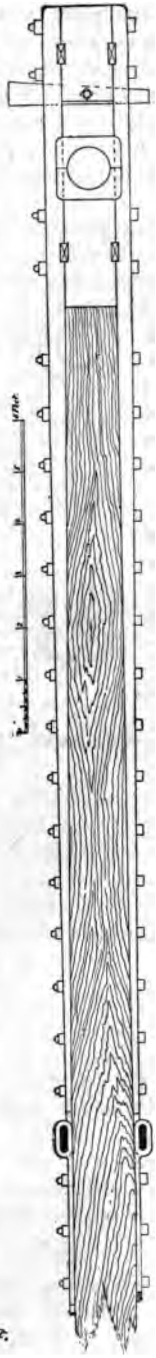


FIG. 61.

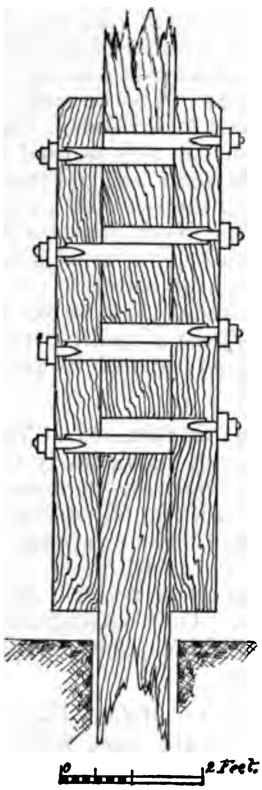


FIG. 62.

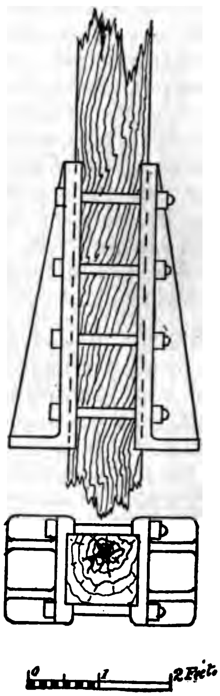


FIG. 63.

to supports or bumpers fixed in the shaft. Either the catches or the bumpers must be armed with elastic cushions to break the force of the blow.

2.2.29. In order to reduce the stresses due to arresting the falling rod, the energy of the fall can be consumed gradually by causing the rod in its fall to perform some work of deformation or friction, such as breaking successively the individual boards of a pile, or causing a tightly gripping clamp to slip a short distance on the rod, which will bring it gradually to rest.

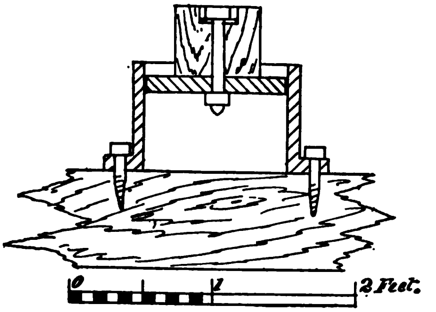


FIG. 64.

2.2.30. Catches and stops or bumpers are particularly needed with engines of the non-rotative type, because with these there exists also the danger of the stroke becoming greater than its intended limits, through variations in steam pressure or neglect in regulation of the pumps. Such engines also require catches to limit the up-stroke, though only one or two are required close to the engine; generally at the beam. These engine-catches and stops require to be only moderately elastic, as they merely operate to prevent the engine from exceeding the proper limits of its stroke during its regular work, while the rod-bumpers have to consume the energy of a weight falling possibly a distance equal to the stroke of the pumprod.

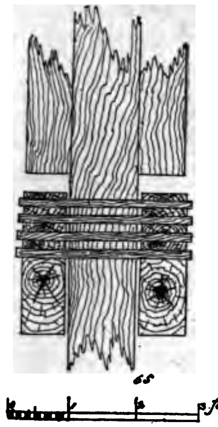


FIG. 65.

2.2.31. Fig. 62 shows wooden catches, and Fig. 63 catches of cast-iron clamped to a wooden rod. It is best to secure the catches to the rod with bolts not passing through the latter, as shown, because then the bumpers can slip a little under a heavy fall, while the blow will be less severe, as the friction work produced by the slipping will help to gradually consume the energy contained in the falling rod. Clamping on the catches also secures their adjustability.

2.2.32. The elastic cushion or bumper proper is usually most conveniently attached to the fixed bumper-frame. The one shown in Fig. 64 consists of cork or old rope confined in an iron box or cylinder, and covered by an iron plate with a wooden block, on top of which the catches strike.

2.2.33. Fig. 65 shows a bumper constructed of boards with intervening spaces. The boards are successively broken by the catches on the falling rod, and by their resistance to breakage gradually lessen, if not entirely consume, the destructive energy of the falling rod before the last board is broken.

2.2.34. In constructing rod-bumpers the distance passed through by the rod in overcoming resistance must not be as great as the space in the pump-barrel below the plungers when in their lowest position; otherwise, the plungers will strike the bottom, and parts of the pump may be broken. Similarly other projecting attachments of the rod or

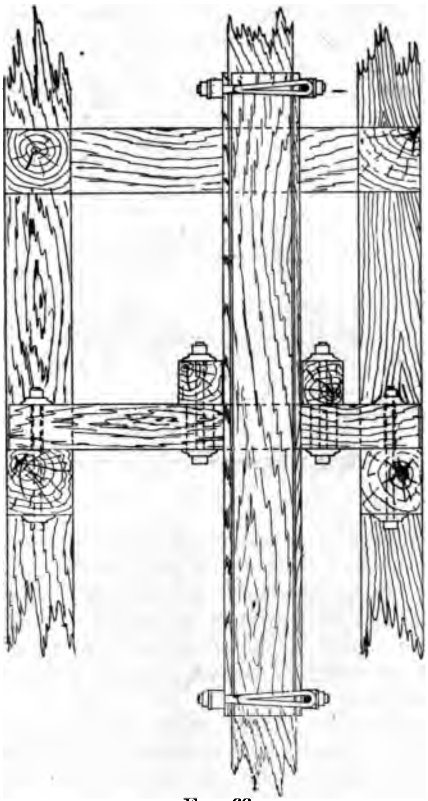


FIG. 66.

balance-bobs must not come closer in operation to fixed parts than permitted by the range of the bumper. It is a good plan to place a bumper above every set of pumps.

2.2.35. *Guides or Stays.* Pump-rod guides, also called stays, should be placed sufficiently close together to render the rod safe from buckling under compressive strains, and they should be kept carefully in line

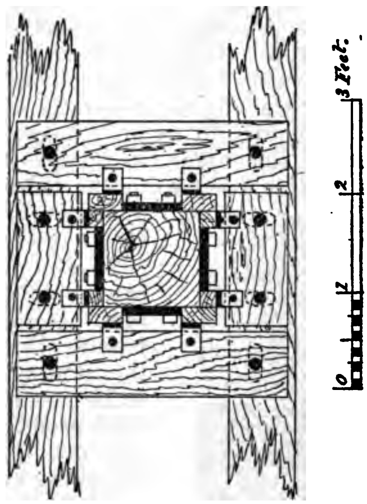


FIG. 68.

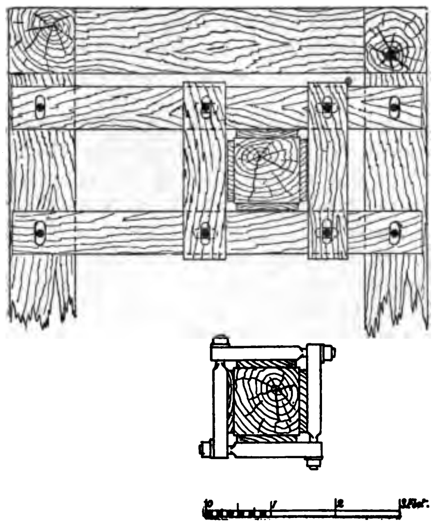


FIG. 67.

where these strains are great. They should always be located as near as possible to points where lateral strains might cause deflection, as above and below balance-bob and pump connections. The guide frames are fixed to the shaft timbers, and are provided with wearing-blocks made adjustable for taking up wear and keeping the rod in line, and the rod is armed with inter-

geable wearing-strips at the guides. Fig. 66 shows a guide with len wearing-strips on the rod, the strips consisting of pine boards, h should not be nailed to the rod, but clamped to it at the ends frame of eye-bolts, as in Fig. 67, called "lamb's legs" by the r. Where strap-plates occur on od, a construction hat shown in Fig. ıust be used. On ınt of the reduced ce, the wearing-s and wearing-s are faced with ron. For the sake ıiformity, all the s are often made same as those at trapping-plates.

.36. The lubri- mostly used with s are tallow for , and a mixture heap mineral oil tallow for iron. ny compound and grease are too ex-ive for general use.

.37. It was men-d in 2.2.26 that en main pump-are generally con-d directly to the n the nose of the ı or bob operating od, and that there-e upper end of the is deflected alter-y in opposite di-ons, while its lower ollows the arc de-ed by the bob- The aim should o distribute this ction of the rod rmly over a con-able length so as inimize the deflec-

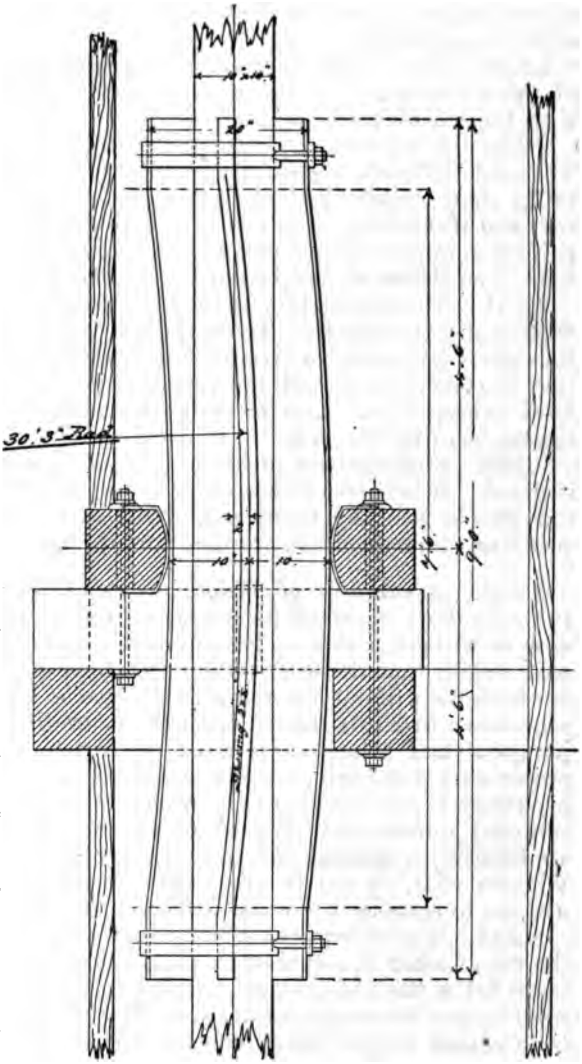


FIG. 69.

strains. The greater the deflection and the larger the rod, the r must be the part over which the deflection must be distributed. rder to obtain the least and at the same time the most uniform ction strains, the rod must be curved to the arc of a circle. It is fore necessary to stay and guide each part in its proper path. part of the rod working in the guides which fall within the range

of deflection has therefore iron curved wearing-strips, as shown in Fig. 69, the amount of curvature being greater the nearer the guide is to the upper end of the rod. Such an arrangement of guide and wearing-strips is generally called a "sweep-stay."

2.2.38. The proper distance apart of guides depends upon the load on the rod and upon its cross-section, and can be determined properly only by calculation.

2.2.39. Where lateral strains are introduced, guides should be made of extra strength, and the wearing-surfaces increased correspondingly with the greater pressure.

2.2.40. Pumprods in inclines are supported and guided by rollers. The guide-rollers are generally stationary and supported in frames fixed to the shaft timbering. Sometimes, however, rollers are attached to the rod, and travel with it on tracks and under fixed top guard-rails. The points of support should be numerous, in order to prevent sagging of the rod. The rollers should be adjustable to enable keeping the rod in line.

2.2.41. The application of the Cornish system in inclines is attended with many drawbacks. The rods are, on account of sag, less able to bear great compressive strains; the friction is great where the inclination is considerable, and the plungers wear on one side only and are hard to keep tight. Less speed is also admissible on account of greater masses than for the same lift in a vertical shaft.

2.2.42. Sinking-rods inside of a sinking-column cannot be used in inclines. It is therefore necessary to use a jackhead pump with outside rod guided like the main rod, unless direct-acting pumps, driven by steam or compressed air, are used for sinking.

2.2.43. *Adjustment of Weight of Pumprods; Balancing Appliances.* In designing a pumprod for operating a series of single-acting plungers, with or without a sinking lift-pump, the aim should be to get the rod of such weight that the work on the up-stroke shall be equal to that on the down-stroke without resorting to the use of balancing mechanism. It was shown in 2.1.04 that in order to secure this result the weight of the pumprod and attachments must be equal to one half the aggregate pressure on the plungers, plus one half the upward thrust due to the buoyancy of the sinking-rod (where this operates inside the sinking-column), minus the total pressure on the lift-pump-bucket. Balancing appliances in general can only be avoided by the use of iron rods. Wooden rods, in nearly every case of deeper mines, require counterweights to equalize the work of the two strokes.

2.2.44. The overweight of rods may sometimes be balanced without the use of other appliances, by placing the plungers a considerable distance below the supply-tank, thereby increasing the height of both the suction- and discharge-columns, so that the work on the suction-stroke is decreased by the lifting effect of the downwardly extending suction-column, and that on the forcing-stroke increased by an equal amount due to the increased height of discharge column. This plan is, however, only applicable where a moderate amount of balancing is required, as it subjects the plungers to higher pressure and greater friction, and is liable to cause heavier shocks, while it also reduces the admissible speed at which the pumps can be safely operated.

2.2.45. The use of larger pumps operated at lower speeds may also sometimes serve to overcome a moderate difference in the work of the

the speed at which the pumping-system may be safely permitted to operate, but it also permits higher degrees of expansion to be used in the case of operating by non-rotative engines.

2.2.53. Hydraulic counterbalances, consisting of a plunger operating in a barrel like that of a pump, against a column of water, which constitutes the counterweight, are more objectionable than the rigid balance-bob.

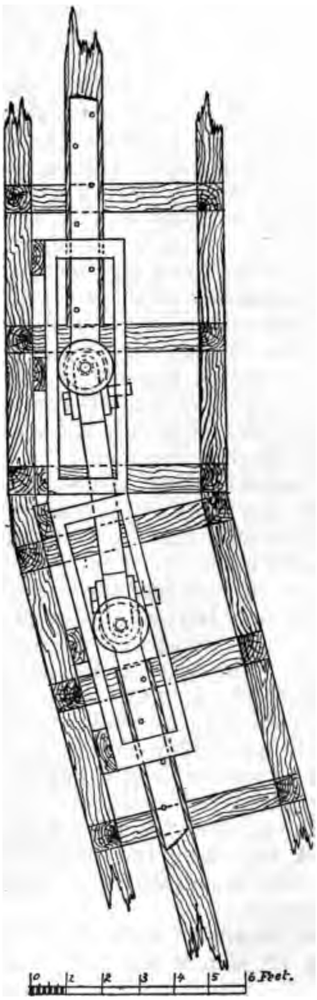


FIG. 80.

2.2.54. By using compressed air, instead of a column of water, in a similar manner, a counterbalance is obtained without the evil of increased mass. Such counterbalances require no excavations like balance-bobs.

2.2.55. The distance apart at which counterbalances are required depends greatly upon conditions. The closer they are together, the smaller will be the units and the less will be the maximum compression strains on the rods, but the greater will also be their cost, particularly if the balancing appliances require the excavation and timbering of stations. Counterbalances decrease the tensile strain and increase the compression strains in the rod. Their distribution and amount should be determined by careful calculations.

2.2.56. The rod can sometimes be divided, and the two parts connected to opposite ends of a beam, as shown in Fig. 73, thus obtaining a balance without the use of extra counterweights. The plan illustrated was carried out at a mine in Belgium, but can only have application under special conditions, as the offset in the shaft is objectionable. The offset could in some cases, however, be avoided by such a construction as shown in Fig. 74 or Fig. 75.

2.2.57. The principle just illustrated can often be applied with advantage where a change of direction necessitates a bob or bell-crank to connect pumprods at an angle; the bob can be designed and located so that the rods take hold of opposite arms of the bob and balance each other more or less completely. Such an arrangement, shown in Fig. 76, was introduced in the Lady Bryan Mine, near Virginia City, Nev. The double pumprod arrangement used at the Alta Mine, Virginia City, and illustrated in Fig. 77, also affords a perfect balance, a moderate counterbalance being only required when the lift-pump work is done entirely by one of the rods. The double rod arrangement, however, takes up considerable room in the shaft.

2.2.58. *Changes in Direction of Pumprods; Angle-Bobs.* One very good arrangement has already been described in the preceding para-

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graph. It is, however, not always possible to place the bob as shown in Fig. 76, and other less advantageous constructions have to be used. Figs. 78 and 79 illustrate forms of bobs and bell-cranks that are common. In Fig. 79 the bell-crank serves also as balance-bob.

2.2.59. Slight changes in direction are often made without the use of bobs or bell-cranks, by having the ends of the rods fitted with rollers guided in straight lines, and simply coupling them by a link, as shown in Fig. 80.

2.2.60. *Strains in Pumprods.* During the up-stroke the main pump-rod is in tension, due to the weight of the rod and attachments plus the pressure of the column of water on the lift-pump-bucket. On the down-stroke the strains change to compression, and these are due to the excess of the resistance overcome by the plungers over and above the weight of the rod. The counterbalances reduce the tension strains above the sections where applied by an amount equal to the upward force exerted by them, and increase the compression strains by an equal amount. The resultants of these strains are modified by those due to the inertia of the rod attachments and counterweights; that is, by the force required to give the rod the required velocity in a given time during the early part of the stroke, and that required to be subtracted from the motive force during the final part of the stroke, so that the rod may come to rest quietly within the limits of its travel. In addition, bending strains are often introduced by lateral disposition of single plunger pumps, or sinking-rods. Those due to the latter are of little moment, because they occur near the lower end of the rod, where the other strains are light. The upper end of the rod is generally strained the most in tension, while the point at which the greatest compression strain occurs depends upon the distribution of pumps and balancing appliances.

2.2.61. Owing to their elasticity, long pumprods extend considerably under tension on the up-stroke, and shorten under compression on the down-stroke. The result of this is, that the lower pumps do not operate at their full stroke. Another result which follows, and is intensified by the inertia of the rod, particularly at higher speed, is, that the upper part of the rod will be already in motion and will have performed a portion of its stroke when the lower end of the rod begins its motion. It is therefore evident that the ends of the strokes of the successive pumps attached to the rod at different levels cannot occur at exactly the same time. Attention was first called to the logical necessity of these results by Hraback and Bochkolz. (See Hauer, Wasserhaltings-machinen.) Experiments made by W. R. Eckart, in 1880, on pumps of Comstock mines, proved the correctness of this reasoning.

2.2.62. Wooden rods are more elastic than iron ones. Their weight is also greater for the same strength, and therefore the variation in extent and coincidence of stroke of pumps must be greatest with wooden rods.

2.2.63. *Wire Rope.* Single wire ropes are occasionally used instead of rods for operating draw-lift pumps, in which case there must be a heavy weight connected with the bucket to effect its down-stroke. A recent arrangement of this kind which has been successfully used for sinking-pump work in a deep mine in Bohemia is described in 2.3.33 and 2.3.34

2.2.64. Two wire ropes connected to opposite ends of double-armed levers at the surface and bottom, so as to act like a rigid rod, have been also used for double-acting pumps at moderate depths. This system has, however, only limited application.

CHAPTER III.

Sinking-Pumps.

2.3.01. *Types of Sinking-Pumps.* It has already been stated in 1.1.03 and 2.1.02 that where pumps are operated by rods, as in the Cornish system, the lowest or sinking-pump, unless it be of the direct-acting, steam-pump type, is nearly always a lift pump, because this type can be more readily operated and repaired when obliged to work under water. The lift pumprod, where the total lift is too great for one pump and one or more plungers are needed above the sinking-pump, is usually coupled to an offset bracket bolted on the main pumprod, as described in the preceding chapter (2.2.04 and 2.2.22). Where the total lift is within the range allowable for the sinking-pump, it is worked directly from a bob driven by a steam engine or other motor.

2.3.02. Sinking-pumps in deep shafts have in some recent cases been operated by a wire rope, worked by a bob. (See 2.2.63.)

2.3.03. Sinking-pumps are subject to much greater wear and tear in the shaft than the other pumps, because in their case it is not practicable to settle the sand or mud from the water before it enters the pump, which can very easily be done with the other pumps.

2.3.04. In designing a sinking-pump the aim should therefore be more to secure uninterrupted operation, or facility for rapid repairing, than economical pumping. Economy is not of great importance here, particularly in deep mines, where the sinking work usually constitutes but a small proportion of the entire pumping work.

2.3.05. The ordinary or English form of lift pump, generally used in vertical shafts, has its working-barrel in line with its discharge-column, and the sinking-rod works inside the latter. Fig. 81 illustrates a common type of Cornish sinking-pump. The suction-pipe is either a rigid casting, as shown, with which the pump rests on the bottom of the shaft, or it is made with a slip-joint so that it can be raised or lowered while the pump is temporarily secured, or it is simply a suction-hose with strainer, as in Fig. 82. The pumps are usually attached to a sinking-frame guided in the shaft, as in Fig. 83, the frame with pump being raised or lowered, as required, by chain-blocks, winches, or a special pump-hoist at the surface. In most instances, the sinking-frame is only as long as the pump, and the column-pipe is guided independently. The pumps with rigid suction-pipes are often not guided in the shaft, so that the lower end of the suction-pipe may be swung around to a limited extent. The chamber for the suction-valve below the working-barrel is fitted with a door for gaining access to the valve. A casting with a door is placed on top of the working-barrel to get at the bucket without having to draw it up through the entire length of the column-pipe, which need only be done when the pump is submerged. This type of pump being all in one line with the column-pipe, occupies very little room in a shaft, and is therefore most generally used with the Cornish system in vertical shafts.

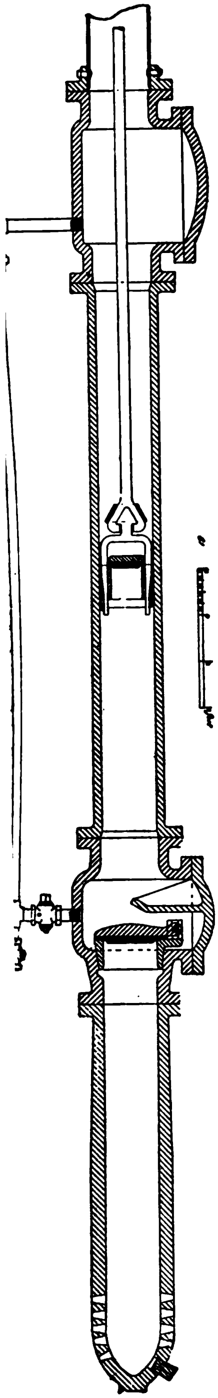

FIG. 81.

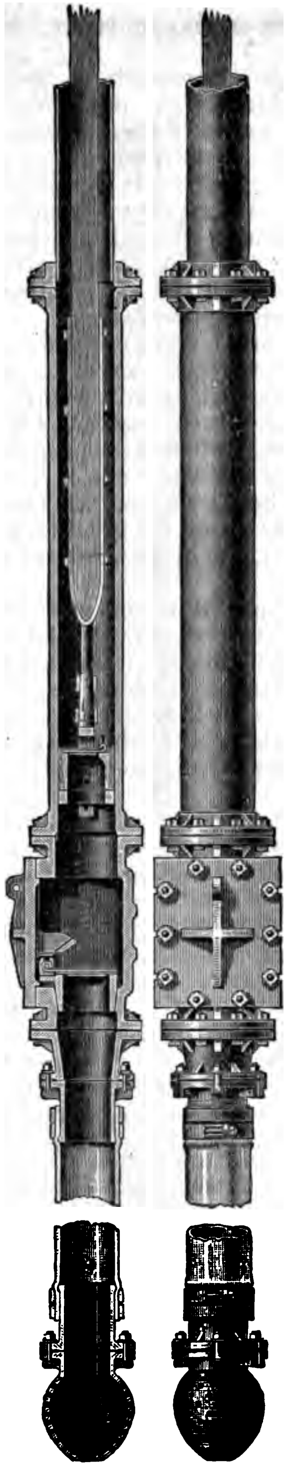

FIG. 82.

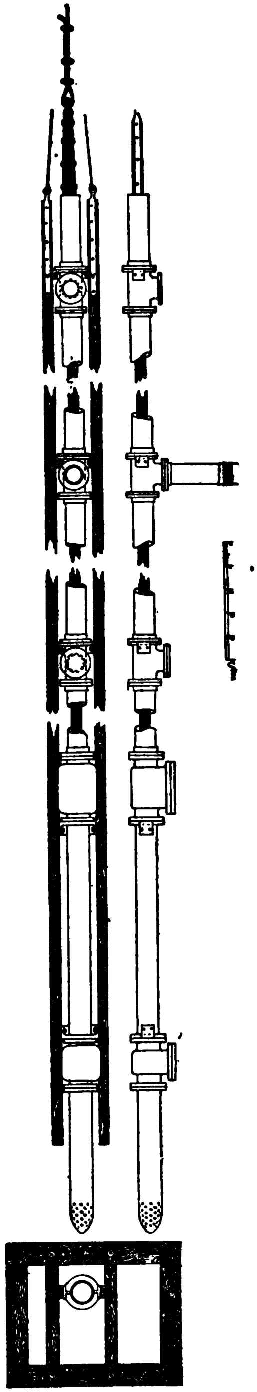

FIG. 83.

2.3.06. In inclines it is not possible to use the kind of pump just described, because, as stated in the preceding chapter, the rod would rub heavily against the inside of the column-pipe and soon wear it through. It is, therefore, necessary to use a pump having the rod outside of the column-pipe. The jackhead lift-pump (Fig. 84) is of this kind. The column-pipe is here laterally connected at the top of the working-barrel by a gooseneck, while the bucket rod passes out through a stuffing-box in a cover, bolted to the top of the pump-barrel, and is connected to the sinking-rod outside. In inclines particularly, the latter must be guided like the main pumprod.

2.3.07. The arrangement of jackhead pumps varies with reference to relative position of valves. Some have the suction-valve below the working-barrel, like the English sinking-pump. In others, the valve in the bucket constitutes the suction-valve, and the discharge-valve is placed above the gooseneck, which arrangement admits of taking out the bucket without letting the water out of the column-pipe. Another form has a valve below the barrel and one above the gooseneck, as in Fig. 85. It is evident that where the usual hinged valve or clack is used with jackheads in inclines, the hinge must be at the upper edge of the valve.

2.3.08. Jackhead pumps cannot be operated under water for any length of time, because the vital part (the bucket) which requires frequent repairs cannot be hauled up through the column-pipe. They are, therefore, usually attached to long frames, which are sometimes sufficiently long to carry also the column-pipe, the whole frame being mounted on rollers, or otherwise guided, and arranged for hoisting, by means of tackle or engines, when the pump is submerged and requires repairs.

2.3.09. Although the bucket lift-pump is generally used for operation by rods in sinking, specially designed sinking plunger-pumps are also occasionally employed where there is no danger of being drowned out, or where the pump can be arranged to be hauled up for repairs. The plunger will remain tight much longer than the bucket, as it is not exposed to wear from sand, but it cannot be arranged to be packed when the pump is under water.

2.3.10. In many applications of the rod-pumping system in the present practice on this coast, particularly in inclines, and in places where lift pumps would be subject to excessive wear, direct-acting sinking-pumps, operated by steam or compressed air, are used. Such pumps are described in the chapter on "Direct-Acting Pumps."

2.3.11. *Sinking-Rod.* In the regular Cornish system the sinking-pump is operated from a bracket bolted to the main pumprod, as described in 2.2.04 and 2.2.22, and illustrated by Figs. 57, 58, and 59. The sinking-rod is clamped to the bracket in such a manner that it can be quickly loosened, lowered, and secured again, as sinking proceeds. The sections of the pumprod, except the topmost one, should be short, so that they can be easily handled, and all should be of equal length; then, knowing the number of sections, the distance to the bucket can be quickly figured out and its position in the pump-barrel determined. (See also 2.3.16.) The rod sections not in use are generally brought to the surface. The top of the upper section of the rod should carry a bail or ring for attaching the cable to raise the rod; the length of this sec-

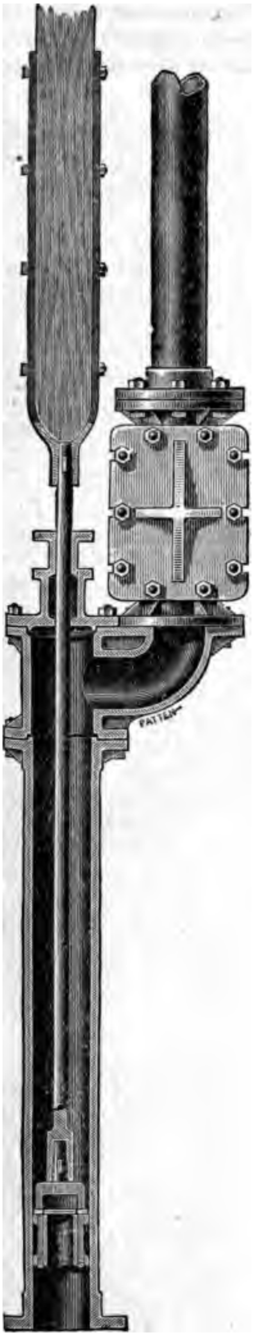

FIG. 84.

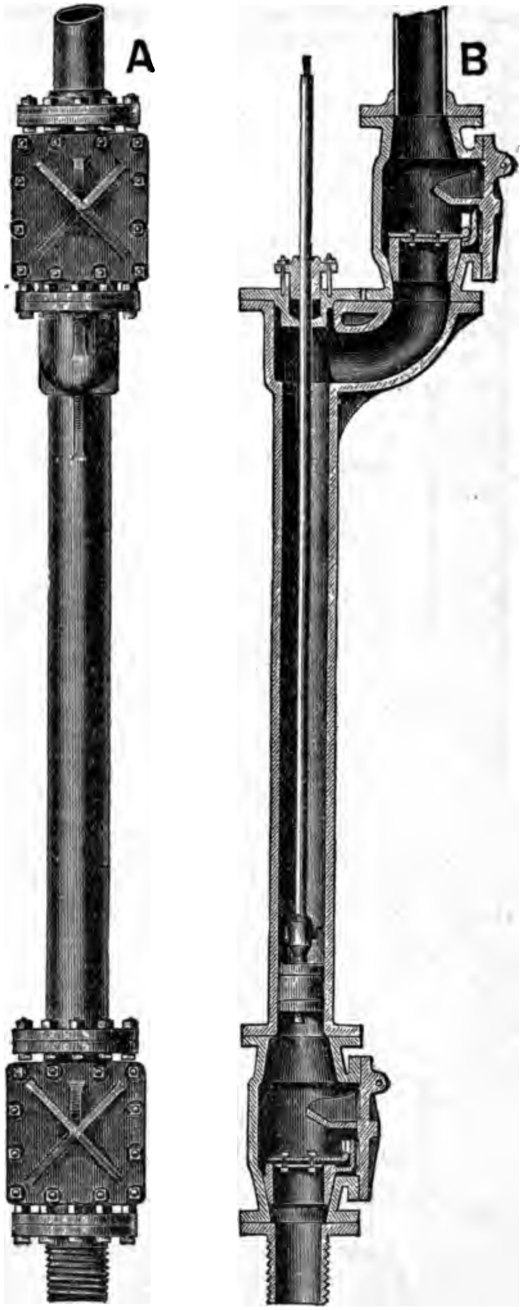

FIG. 85.

tion should be sufficiently greater than that of the other sections, so that one of these with its joint or strapping-plates can be inserted below the clamps, when the top of the upper section has been lowered as far as the clamp, and then raised so as to admit the new section below it.

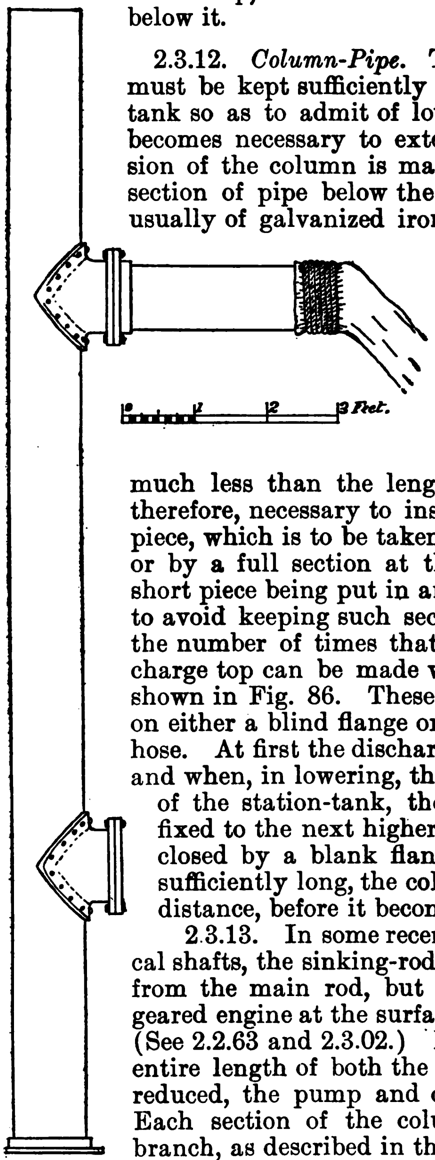

Fig. 86.

2.3.12. *Column-Pipe.* The discharge from the column-pipe must be kept sufficiently high above the top of the station-tank so as to admit of lowering for some distance, before it becomes necessary to extend the column-pipe. The extension of the column is made, as with the rod, by inserting a section of pipe below the discharge top; the latter is made usually of galvanized iron, for the sake of lightness, with a lateral branch, generally carrying a canvas hose, leading into the station-tank or into a launder connected with it. (See Fig. 24.) In order to save time, the column-pipe is usually lengthened whenever a new rod section is inserted. The amount of column extension to be made at one time is generally much less than the length of a full section of pipe; it is, therefore, necessary to insert, for the first section, a shorter piece, which is to be taken out and replaced by a longer one, or by a full section at the next extension, and so on, the short piece being put in and taken out alternately. In order to avoid keeping such sections on hand, and also to reduce the number of times that extensions must be made, the discharge top can be made with several discharge branches, as shown in Fig. 86. These branches have flanges for bolting on either a blind flange or a thimble carrying the discharge-hose. At first the discharge takes place at the lowest branch; and when, in lowering, this has reached the level of the top of the station-tank, the discharge-hose is taken off and fixed to the next higher branch, while the lower branch is closed by a blank flange. By making the discharge top sufficiently long, the column can be lowered a considerable distance, before it becomes necessary to extend it.

2.3.13. In some recent lift sinking-pumps for deep vertical shafts, the sinking-rod in the column-pipe is not operated from the main rod, but by means of a wire cable from a geared engine at the surface, which also serves as pump-hoist. (See 2.2.63 and 2.3.02.) In one arrangement referred to, the entire length of both the pumprod and column-pipe is never reduced, the pump and column being lowered as a whole. Each section of the column-pipe has a lateral discharge branch, as described in the preceding paragraph. All of the branches below the one discharging into the station-tank of the next higher pump are necessarily closed by blank flanges. As the column-pipe is lowered, the higher branches are successively used as discharge-pipes. The arrangement described admits of rapid manipulation in sinking, and is well suited for this purpose. Wire ropes are,

however, on account of their elasticity, not to be recommended for operating fixed pumps in permanent installations.

2.3.14. Pumps operated by rods or ropes are sometimes used for sinking, when the other shaft pumps are direct-acting steam or compressed-air pumps.

2.3.15. The column-pipe, or at least the upper part of it, must be guided in its descent in the shaft. The guides are usually wooden pieces, cut out to fit the pipe, and bolted to or wedged against the shaft-timbering in such a manner that they can be separated in order to allow flanges to pass.

2.3.16. *Pump-Barrel.* The pump-barrel is generally considerably longer than required for the stroke of the bucket, so that the latter need not always be lowered whenever the pump is lowered a moderate amount. Some lift pumps have a stop at the lower end of the barrel, formed by the reduced opening of the suction clack-chamber, which prevents the bucket from dropping into the chamber. In lowering the rod this stop can serve to indicate the position of the bucket. (See 2.3.11.) The barrel is usually made of cast-iron, and being bored its inner surface is liable to rapid destruction in case of acid water. Brass and copper linings are sometimes used where the water is very bad. The barrels of sinking lift-pumps are also subject to great wear from grit in the water.

2.3.17. *Suction-Pipe and Strainer.* As described in 2.3.05, the suction-pipe is either a rigid, heavy casting bolted to the pump, which is supported by it on the bottom of the shaft, or it is made extensible after the manner of a telescope, or it consists of a flexible suction-hose, in both of which last-named cases the pump and the column-pipe must be supported, when not being lowered, by timbers on the shaft sets.

2.3.18. Fig. 81 illustrates a pump with a rigid suction-pipe. It is made very heavy, so as not to fracture under the blows from flying rock when blasting. It is generally further protected by planks, which cushion the blows of large rocks. Often for this purpose the suction-pipe or -hose is permanently wound with old rope, canvas, or similar material. When the suction-pipe is heavy, it is even admissible to blast right under it. The bottom is shaped to a rounded point, so that drills can be operated close under the suction. The strainer-holes should be conical, with the larger diameter inside, so that small pieces of rock will not jam into the openings. It is well to have two or three larger openings, ordinarily closed by wooden plugs, for getting out any small pieces of rock which may have been drawn into the strainer.

2.3.19. The suction should always be at the lowest part of the shaft, so that the men will not have to work in any deeper water than necessary. If the pumprod is long, the pump with column and rigid suction can be swung out of line to some extent, so as to allow placing the suction in the most advantageous position within the reach of the deflection. (See 2.3.05.)

2.3.20. The flexible suction has the advantage that the suction end, which is fitted with a strainer, can be moved to any part of the shaft bottom, so as to reach the lowest point, wherever that may be located. It also permits placing a foot-valve above the strainer, which is an advantage in many cases. (See 3.2.05.) Suction-hose is made of rubber, with layers of canvas between, and has a steel or iron stiffening-spiral

on the inside, to prevent it from collapsing. In some hose the spiral is again covered inside with rubber, to prevent corrosion.

2.3.21. The suction height is the vertical distance from the bucket to the water-level in the sump. Its admissible maximum is much less in high altitudes than at sea-level. High speed of pumps, narrow and long suction-pipes, and great resistance of suction-valves also tend to reduce it.

2.3.22. If the water carries much sand, it is well to make the suction-pipe large, for then the velocity of flow will be reduced, and less sand will be drawn into the pump.

2.3.23. If the water in the sump is lowered, so that the upper strainer-holes are exposed, these are plugged up by the men working in the bottom of the shaft. Small quantities of air entering in this manner find their way through the valves into the column-pipe. If too much air has been drawn in, so that the pump loses its suction, it must be primed, or the sump-water must be allowed to accumulate to such a depth that the pump will prime itself. This it will do the more readily, the less the volume of the space between the suction-valve and the bucket in its lowest position as compared with the volume of the pump displacement, because the air will be the more rarified the greater the ratio of these two volumes. Self-priming will also be the more readily accomplished the smaller the suction lift as compared with the barometric head.

2.3.24. *Suction-Valves.* The suction-valves of sinking-pumps are often at a considerable height above the water-level in the sump; it is therefore important that they should open easily, as the available amount of overpressure beneath, tending to open them, may be only slight. Light valves naturally open more readily than heavy ones, and small valves can be made more than proportionally lighter than large ones, so that the use of multiple valves would be of advantage in this respect. (See 1.3.20 and 1.3.21.) Multiple valves cannot well be designed to admit of hauling up through the column-pipe, but this is not generally provided for in modern plants, as direct-acting steam sinking-pumps or large bailing-tanks can generally be used in case of emergency.

2.3.25. Suction-valves of sinking-pumps should be so constructed that they may last and remain tight for as long a time as possible. They should, however, be readily accessible to facilitate repairing when needed. The suction-valves are generally single or double clack-valves. The valve-chambers are made as described in 1.3.02 and illustrated in Fig. 48. They are often made extra heavy, to admit of their being brought down closer to the sump, where they are more subject to the effects of blasting. Extra clack-chambers, with valves in place, and also suction-pipes, should be on hand and in readiness to replace broken ones with the least possible delay. Steel cast valve-chambers have recently come into use. They can be made much lighter, and at the same time are less liable to breakage, than those made of cast-iron. The greater lightness of steel doors facilitates their handling when changing valves.

2.3.26. *Buckets.* Lift-pump-buckets should be so arranged that they give the greatest possible area for the passage of water through them on the down-stroke, and they should fit the barrel as closely as possible. When much sand is carried into the pump-barrel, the buckets have

sometimes to be taken out and fitted with new packing every few hours. The valve in the bucket is generally either a clack or a straight-lift valve. Conical flexible valves have been used, but are suitable for only low lifts; they are extensively used in hand pumps. Leather is the most common material for packing the body of the bucket against the pump-barrel. It is so arranged that the pressure of the water will force the leather against the bore of the barrel during the up-stroke. Fig. 87 illustrates a common form of lift-pump-bucket. The ends of the leather forming the ring are beveled off and riveted together by

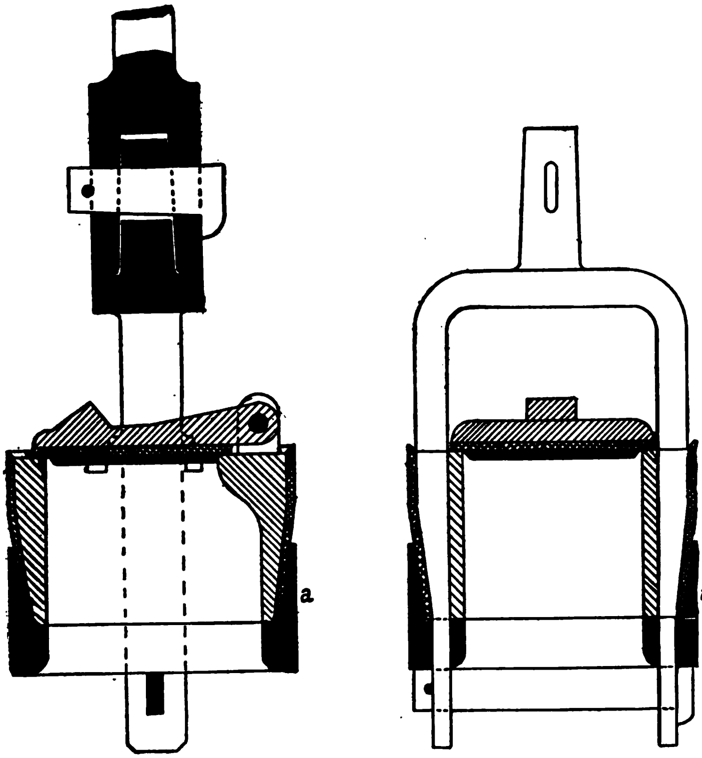

FIG. 87.

copper rivets. The leather should be of the best quality, and should present the flesh side as wearing surface, so that the more compact, hair side, which holds the leather together, will remain intact. It is best to soak the leather in tallow for some time before using. The packing is held in place by the taper-bored ring *a*, secured by a follower and key. The body of the bucket is made either of cast-iron or brass. The yoke by which it is connected with the rod, and the bevel ring and follower, and generally the valve also, are of wrought-iron.

2.3.27. The bucket should be quickly detachable from the rod, and it must be possible to immediately replace it by another, so that the pump need not long remain idle. The bucket taken out should be repaired and kept in readiness for going into the pump when in turn the one in place requires repairs. This can always be seen by the

decreased quantity of water delivered by the pump, and the sinking of the water-level in the tank supplied by the sinking-pump. Key connections to the end of the rod, as shown in Fig. 87, are inconvenient to get at when taking off the bucket at the pump, and often require much time to loosen. The connection shown in Fig. 88 is a very convenient form for this purpose. The tapering sleeve, which surrounds the spear-head and claw, remains in place simply by its weight.

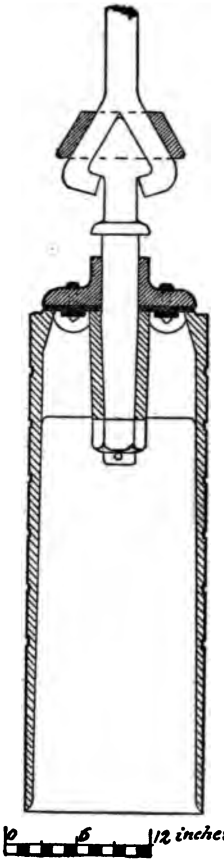

Fig. 88.

2.3.28. Much trouble was experienced in the Comstock mines, Nevada, on account of the rapid wear of lift-pump-buckets. While, in many instances, the Cornish sinking-pumps were entirely discarded and replaced by direct-acting pumps, worked by compressed air, in others, new forms of lift-pump-buckets were adopted. One form of these buckets, which is shown in Fig. 88, was constructed without any packing whatever, it being simply made to a reasonable fit and very long, so that sufficient resistance to leakage past its periphery would be established. Grooves were also turned in its surface, but their efficiency in helping to reduce leakage is doubtful. The body of the bucket was in some instances about 4′ long. The valve was a simple, straight-lift valve. These buckets are said to have worked satisfactorily for a much longer time than those of the older form. The bucket is the weak point of the lift pump; its packing wears out rapidly in mining use. In order to be able to remove it and substitute another bucket, while the pump is submerged, it must be possible to draw it up with the rod through the column-pipe, and the latter must, therefore, be of sufficient diameter to admit of its passage. If the bucket is to be taken out or repaired through the door in the chamber over the pump-barrel, the column-pipe must first be emptied of all its water. In the ordinary form of jackhead lift-pump, the bucket can be gotten at without emptying the column-pipe.

2.3.29. A small pipe is usually placed by the side of the pump, as in Fig. 81, which, on turning the cock *a*, and thereby opening communication between the column-pipe and the space between the bucket and suction-valve, permits the charging of the pump. This cock should be placed down at the lowest part of that space, so that any sand carried into the pump can be periodically blown out. The other cock is for letting the water out of either the pump-barrel or the column-pipe. By connecting it with a float in the sump in such a manner that the cock is opened and lets water out of the column when the sump water-level falls below a certain point, a means could, if desirable, be obtained for keeping the pump charged and working, even when it runs faster than necessary to keep down the water.

2.3.30. *Piston Sinking-Pumps.* Mr. S. N. Knight, of Sutter Creek, Cal., has built sinking-pumps with solid pistons, in which the work is

done on the down-stroke, the pump really operating like a plunger pump. Its construction appears from Fig. 89. The pumprod is here subjected to compression instead of tension, and must, therefore, be very well guided. It requires comparatively little repairing for a sinking-pump, as the course of the water is not through the piston. This pump, like the jackhead, is more difficult to support in a vertical shaft, and it requires more room than the ordinary single-axis lift pump. This construction has many features to recommend its use in inclines, and ought to be preferable, in most cases, to the jackhead. The work being done on the down-stroke has also the advantage that less counterbalance is required for the main rod. The piston must not quite reach to the top of the barrel at the upper end of the stroke, so that there may always be a quantity of water on top of the piston, which will seal it if leaky, and prevent the influx of air on the suction-stroke, while the escape of air past the piston on the working-stroke would not be obstructed by the water. The pump illustrated was constructed with its valve-chambers and other large castings of steel. This makes possible a lighter construction and admits of a somewhat more compact arrangement.

2.3.31. *Admissible Lift of Sinking-Pumps.* The lift of a sinking-pump increases as the shaft goes down, until it becomes necessary to relieve it by placing a fixed plunger pump with tank-station in the shaft. When this plunger is ready for operation, but not before, the sinking-rod is detached from its connection to the main rod above the next higher plunger pump, the rod and column-pipe shortened by taking out the sections between the top and bottom pieces, and the rod clamped to the main rod above the new plunger pump, while the discharge of the column-pipe is diverted into the tank of that pump. The lift pump must therefore be capable of working, at least for a part of the time, against a head a little greater than the highest head under which any of the plungers in the shaft are working. In exceptional cases lift pumps have worked against a head of over 300′. Unless absolutely necessary, however, a head of 200′ should not be greatly exceeded.

2.3.32. The extreme lift of sinking-pumps is quite often kept within moderate limits by dividing the total sinking-lift between two pumps working in a series, so that the lower pump raises to a small tank fixed around the suction-pipe of the upper pump. In this arrangement the upper pump is not put into operation until the limit allowed for the lower, or sinking-pump proper, is reached. The lower pump usually advances as the shaft goes down, while the upper one is temporarily fixed and lowered only at intervals. The latter is usually also a lift pump of the same pattern as the lower one, so that either pump can, in case of emergency, be used for sinking. If anything happens to the lower pump and it is drowned out, the upper one can be lowered and used under increased lift until the lower pump can be drawn up and repaired. In the same way, if the upper pump is disabled, the lower one can have its column-pipe extended to increase its lift, so as to include that of the upper.

2.3.33. An interesting sinking operation described by Professor Riedler, in the Zeitschrift des Vereins Deutscher Ingenieure, Vol. XXXVI, No. 16, 1892, was carried out in 1889–90, in bringing down the Max shaft of the "Prague Iron Industrial Company," in Kladno,

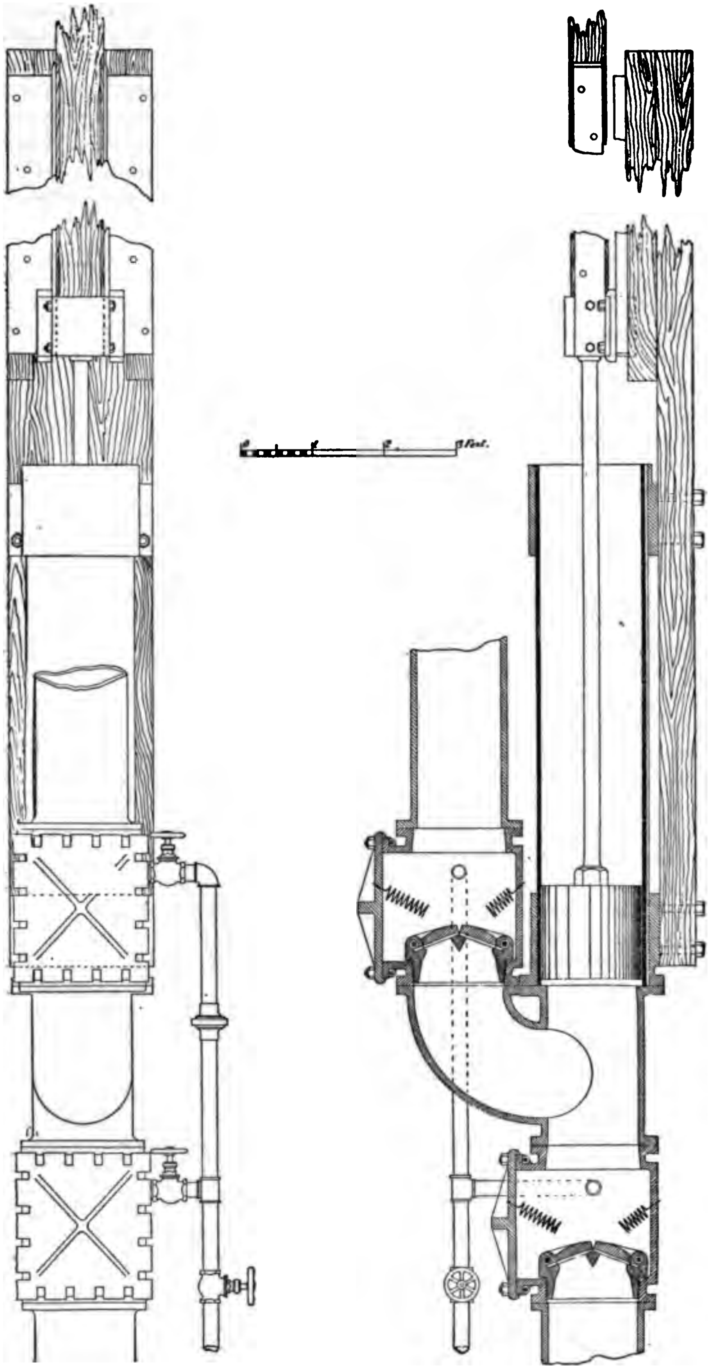

FIG. 89.

Bohemia. Riedler steam pumps were used for the permanent installation, and the extreme sinking-lift came to about 475'. Two sinking-lift pumps of Karlick's patent (which will be described presently) were used in series, after the manner described in the preceding paragraph. The extreme lift allowed for each of these pumps was 200', so that a depth of 400' could be sunk by their combination. The remaining 75' was overcome by the use of a Hall pulsometer. By this arrangement, the most wasteful machine in the use of steam—the pulsometer—was detailed to do the lesser part of the work, while at the same time its heating effect was removed far from where the men worked in the bottom of the shaft. A steam sinking-pump would doubtless have been better than a pulsometer.

2.3.34. The Karlick sinking-pump, illustrated, with its sinking-frame, in Fig. 83, consists of an ordinary English lift pump with the pumprod inside of the column-pipe. The latter is constructed as described in 2.3.13, the sections each having a nozzle, which can be used as discharge or closed by a blind flange bolted on. In sinking, except when doing so from the surface, the sections of the column-pipe always remain connected with the pumps, the water being discharged first at the lowest nozzle, which is opened for the purpose. As the pump goes down, the next higher nozzle is connected with the discharge-hose, and the lower nozzle is closed. In this manner very little time was lost through stoppages. The bucket-rods of the pumps extended only a little beyond the top of the column-pipe, and were there operated each by a wire rope from bobs at the surface. The weight of the pumprod and bucket kept the rope taut on the down-stroke. The ropes were clamped to links hinged to the bob-nose, so that they could be quickly loosened, lowered, and secured again as the sinking went on. The pumprod sections were never disconnected, except for repairs. Breakages of ropes, when they did occur, were quickly repaired by means of clamps. The pumps were made of steel castings in order to secure lightness.

2.3.35. By arranging the pumps with guides for a considerable distance above them, they could be raised when drowned out, and an additional safeguard against the entire flooding of the mine was thus obtained.

2.3.36. The system of sinking just described deserves a wider application, on account of the rapidity with which the different manipulations may be carried out.

2.3.37. *Volumetric Effect of Lift Pumps.* Owing to the wear of pump-barrel and bucket-packing, and the consequent leakage, lift pumps at low speeds raise a smaller quantity of water than that due to the volume displacement of the bucket. At high piston speed the leakage is less in proportion to the volume displacement, and the latter is more nearly approached by the quantity of water raised, particularly in the common lift pump, where the energy of motion of the water assists in its own advancement, sometimes to such an extent that the quantity of water actually raised exceeds by several per cent that due to the volume swept through by the bucket. But when ordinary pumps are run in this manner, their operation is generally accompanied by severe shocks, and the pumping is done with less efficiency and with less security against breakdowns.

CHAPTER IV.

Plunger Pumps.

2.4.01. It has already been stated in 1.1.04 that plungers are more easily packed, admit of pumping against higher heads, and remain tight much longer than buckets or pistons, and that they are much less subject to wear, since the rubbing surfaces are located at such a point that very little of the sand usually carried by the water will reach them. The objection that they cannot be packed under water, applies only where they are liable to be drowned out. The use of plungers also admits of equalizing partially or entirely the work on the up- and the down-strokes, so that much less counterbalance will be required than if lift pumps only were used. (See 2.1.04 and 2.2.43 *et seq.*)

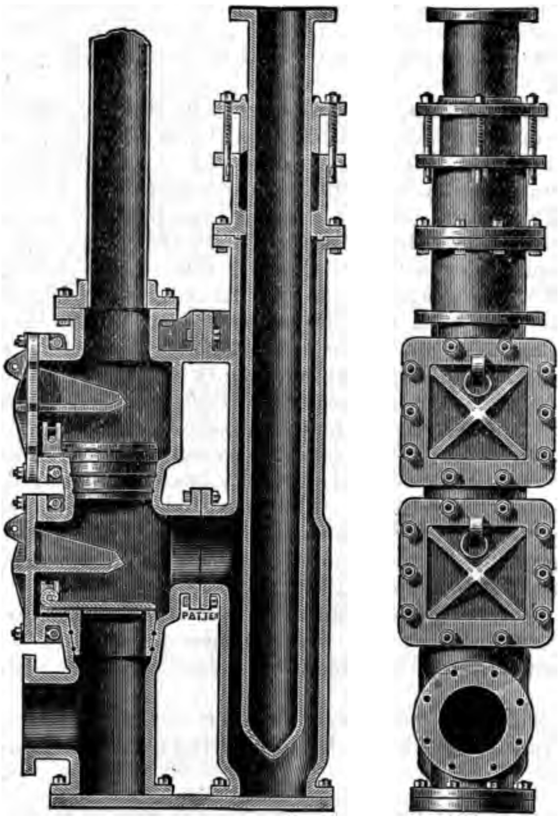

FIG. 90.

2.4.02. For these reasons, the pumps of the Cornish system, with the exception generally of the lowest, or sinking-pump, are designed as plunger pumps.

2.4.03. *Relative Arrangements of Parts.* A usual type of plunger pump for a vertical shaft is shown in Fig. 90. The disposition of valves in relation to the working-barrel is the one which long experience has demonstrated to be the most convenient. This pump can also be used in an incline. The clack-chambers can then either be placed on top or at the side, in which latter case, however, the clacks will have to be turned around 90°. Where straight-lift valves are used in an inclined pump, the valve-chambers should be placed in a vertical position.

2.4.04. *Plungers.* These are generally made of cast-iron, though brass is a better material, as it works through the packing with much less friction than iron. Sometimes, therefore, the plungers are made of or lined with brass. Brass also resists better the action of acid water. Thick grease will protect cast-iron plungers to some extent, if the water

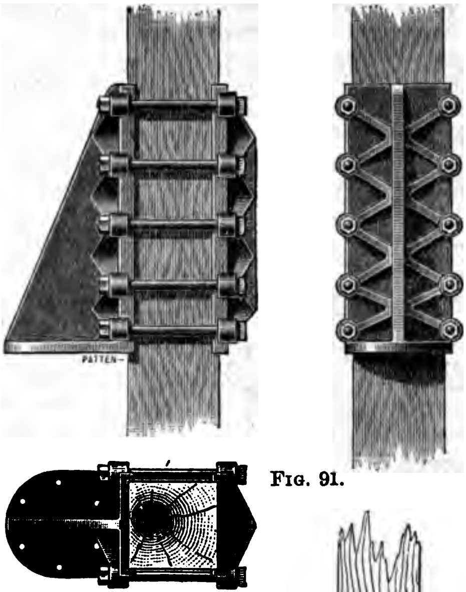

FIG. 91.

; too warm to melt the
: and float it off. The
ers are properly formed
a rounded, point-shaped
n, as shown in Fig. 90, so
reduce shocks on striking
ater in the barrel, in case
ımp does not quite fill on
ıction-stroke. The top is
d with a flange, which is
l to a bracket that is
›ed to the pumprod. Fig.
ıows such a bracket.
e two pumps are attached
›osite sides of the rod the
›ing-plates are dispensed
and two such brackets
n place by the same bolts.
ping the brackets to the
ısures their adjustability.
ɪy also permit a ruptured
ɔ slip through the clamp
: the severe strain due to
.ll, and by slipping prevent injury to the pump.
2.2.29–2.2.34.) Where the lift is so small as to
require a single plunger pump, the plunger is
ıed to the lower end of the rod, and in line with
a split socket casting, as shown in Fig. 92. The
;ers of inclined pumps are subject to one-sided
which makes it hard to keep them tight and hold
akage down to an allowable amount.

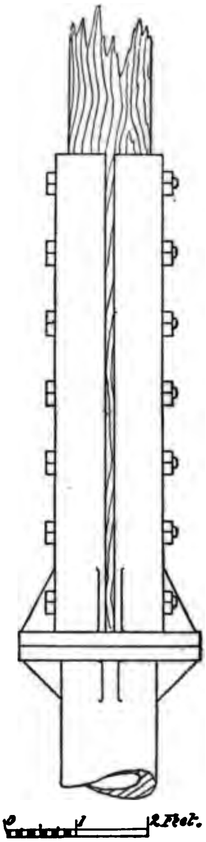

FIG. 92.

05. *Stuffing-Boxes.* The stuffing-box for pack-
he plunger is generally cast separate from and
l to the top of the pump-barrel, as in Fig. 90.
ısual packing consists of square braids of hemp,
ɔr cotton, soaked in tallow, Albany compound,
nixture of tallow with beeswax. For cold water
s of flax, thoroughly impregnated with Albany
ound, give good results. The wasting of the com-
l should be made up by periodically smearing
on the plunger. For hot water this packing is
ıitable, as the compound becomes too fluid and
rried off by the water very rapidly. Square
s of cotton impregnated with powdered plum-
work very well in the hot water. The braids
d be put in in level layers, not wound around
ͽ form of a spiral. For such and other packing
fibrous nature, the bottom of the stuffing-box
ɡland are, with advantage, made in a grooved
as shown in Fig. 93, for by such construction
will be less liable to be dragged along by the

plunger and forced between it and the metal of the stuffing-box, thereby causing one-sided wear of the plunger. The gland, for vertical pumps, should be cast with an annular bead, forming a cup to surround the plunger and keep the grease from spreading. This cup, by being filled with grease and water, also prevents air from being drawn in through the stuffing-box on the suction-stroke.

2.4.06. Ordinary stuffing-boxes generally cause considerable friction, because they are drawn up too tight. They should be drawn up just enough to permit a little leakage. In screwing up the gland, care should be taken to keep it true with the plunger. Plungers wear unevenly, and when it is attempted to prevent leakage by screwing up the packing, the friction becomes excessive. When the plungers are so worn, they should be replaced by spare ones kept on hand. Those taken out should then be trued up and kept ready for putting in again. As they are reduced in size by repeated truing-up, the stuffing-boxes become too wide for the plungers, and they, or their linings, must be replaced by new ones.

2.4.07. With large pumps in inclines, the stuffing-boxes give a great deal of trouble, because the heavy plunger presses on the packing on one side only. (See 2.4.04.)

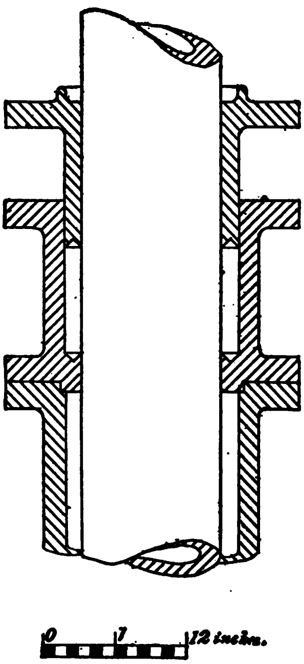

FIG. 93.

2.4.08. *Pump-Barrel.* Where, as in the ordinary designs, the connection to the valve-chambers is about mid-height of the barrel, the part below the connection should have a cross-section area equal to about twice that of the plunger, as in Fig. 90, so that the water can flow freely along the plunger during the lower half of its stroke, to fill or empty the space swept through by it.

2.4.09. With the connection to valve-chambers below the top of the barrel, air will accumulate in the upper part. For this reason pumps sometimes have the connection at the upper end of the barrel. But this makes an inconvenient form to support and place in an accessible manner in the shaft. It is, therefore, better to provide a small pipe-connection from the highest part of the pump-barrel to the column-pipe. On the working-stroke, water will be forced through this connection into the column-pipe, while on the suction-stroke some water will flow back into the barrel. The pipe-connection should therefore be provided with a cock to regulate the amount of opening, and to close it in case the suction-valve has to be inspected. A small check-valve would prevent the back-flow of the water, but in order to be operative it should open easier than the main discharge-valve. Some air generally escapes through the leaky stuffing-box, and many pumps are therefore made without the aforesaid connections.

2.4.10. A cock to let out the air on filling the pump must also be fitted to the top of the barrel, as stated in 1.1.12 and 1.1.13, where the manner of starting and priming pumps is described.

2.4.11. Near the bottom of the barrel there should be a hand-hole, a nipple with valve, to clean out accumulated sediment.

2.4.12. *Valves and Valve-Chambers.* The valves and their chambers are generally superposed as in Fig. 90. Single or double clack valves are most generally used on this coast. The advantages of multiple, light,

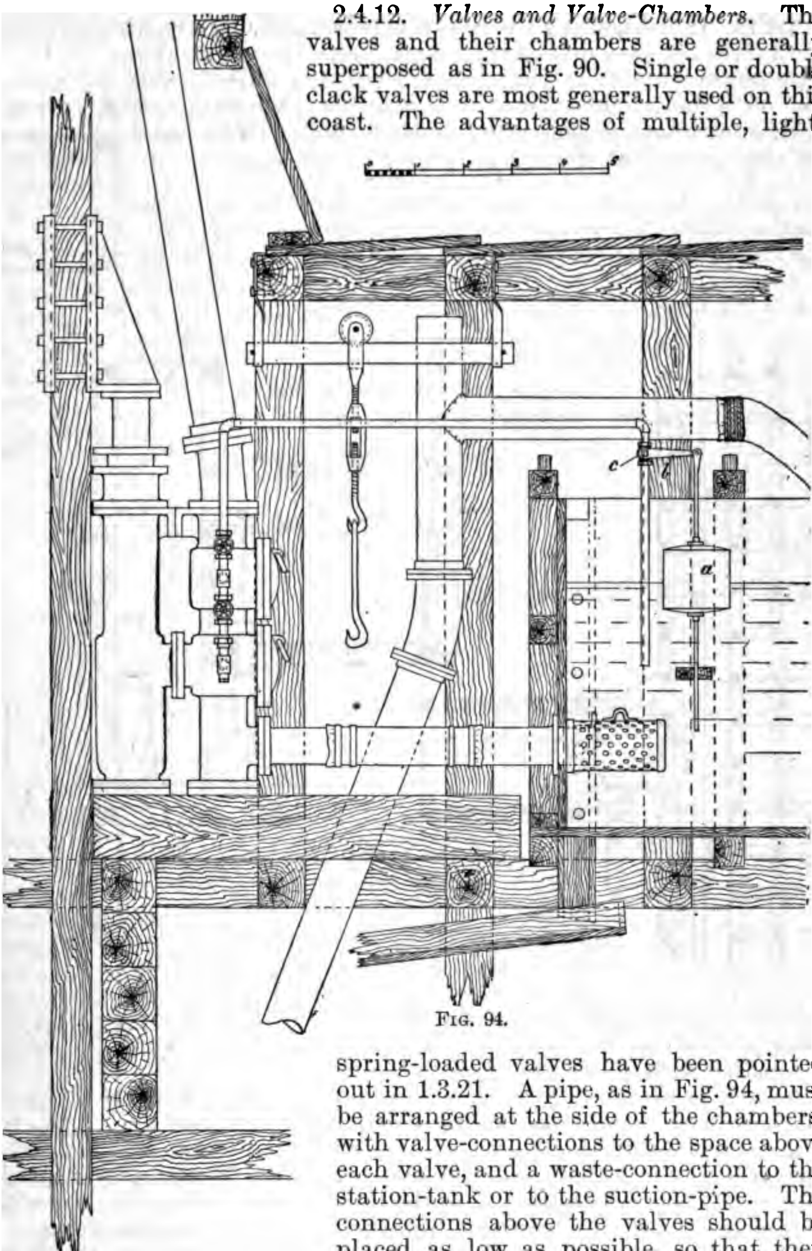

FIG. 94.

spring-loaded valves have been pointed out in 1.3.21. A pipe, as in Fig. 94, must be arranged at the side of the chambers, with valve-connections to the space above each valve, and a waste-connection to the station-tank or to the suction-pipe. The connections above the valves should be placed as low as possible, so that they ay serve to draw off sediment. A cock operated by a float in the ation-tank is generally also placed in the pipe connecting the spaces ove the valves. The arrangement of pipe and valves serves to regu-

late the relative capacity of a series of pumps, according to the varying duty at each station, and it also serves for priming the pump or emptying the column-pipe when necessary.

2.4.13. For handling the heavy valve-chamber doors, when access to the valves becomes necessary, a hook, vertically adjustable by a screw-connection, and suspended from a roller traveling on a bar, either fixed or capable of swinging in a horizontal plane, is generally provided. Fig. 94 illustrates an arrangement of this kind. (See 1.3.22 *et seq.*)

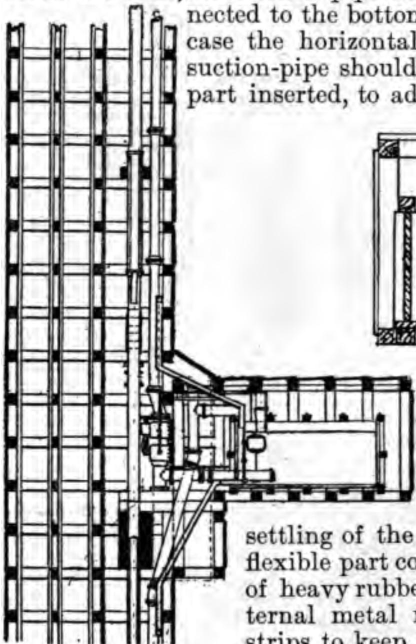

Fig. 95.

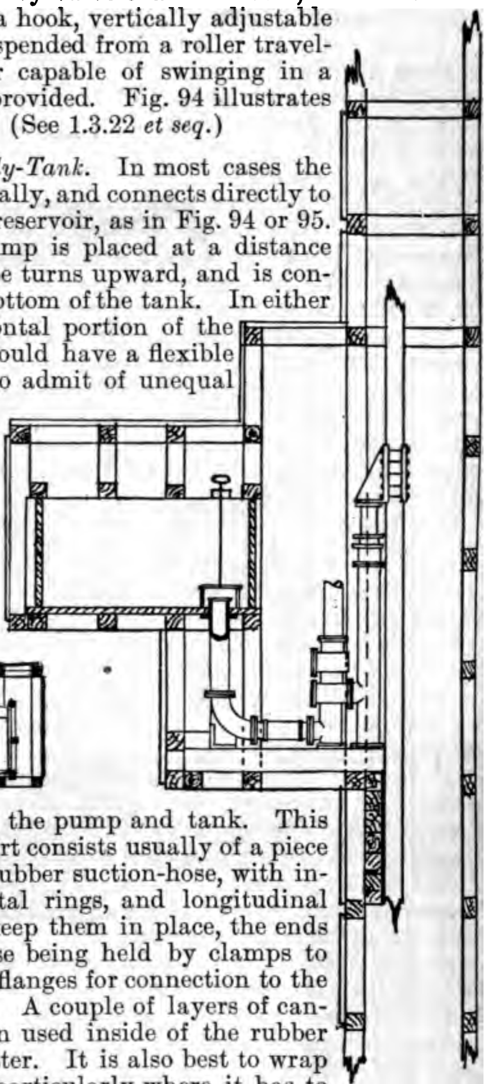

Fig. 96.

2.4.14. *Connection to Supply-Tank.* In most cases the suction-pipe runs only horizontally, and connects directly to the side of the station-tank or reservoir, as in Fig. 94 or 95. Where, like in Fig. 96, the pump is placed at a distance below the tank, the suction-pipe turns upward, and is connected to the bottom of the tank. In either case the horizontal portion of the suction-pipe should have a flexible part inserted, to admit of unequal settling of the pump and tank. This flexible part consists usually of a piece of heavy rubber suction-hose, with internal metal rings, and longitudinal strips to keep them in place, the ends of the hose being held by clamps to thimbles, as in Fig. 97, having flanges for connection to the other parts of the suction-pipe. A couple of layers of canvas coated with pitch are often used inside of the rubber hose, as a protection for the latter. It is also best to wrap the hose with tarred marlin, particularly where it has to withstand considerable pressure, as when the suction is arranged like in Fig. 96. It is evident that the suction-pipe must be air-tight. The end connected to the tank should be a little above the tank floor, to prevent sediment from being drawn into the pump. A strainer of ample area should form an extension of the pipe inside the tank, and should be removable for cleaning. The tank end of the pipe is sometimes flared out to a larger diameter, so that the water will enter with less current, and therefore not sweep in so much sediment. It is

a good plan to arrange the end of the pipe with a tight cover, which, ı the pump is working, is left off, but which can be closed when it sirable to drain the pump for inspection, without also draining the :.

ı.15. *Supply- or Station-Tanks.* Where the station is in hard, self-›orting ground, requiring no timbering to support the roof, a reser- can be made by lining the bottom part of the excavation up to r-level with cement, and throwing up a small masonry dam in t. Generally, however, the stations have to be timbered, and then len tanks are set up, as in Figs. 94 and 95. It is advantageous to the tanks of large capacity, so that they can take up a consider- inflow from levels, or overflow from upper tanks, and prevent it ι reaching the sump.

ı.16. The water from the lower pumps and other sources should into the tanks quietly, with the least possible disturbance of their

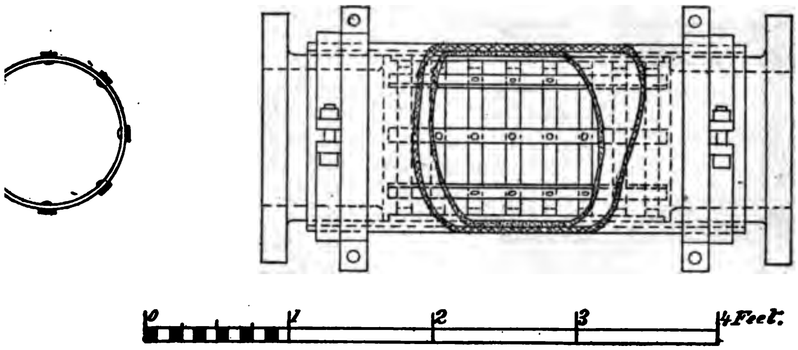

FIG. 97.

ents, in order to give sand and mud a chance to settle. Partitions ıe tanks are useful to confine the bulk of the sediment to those s where the water enters, and keep it from reaching the suction- s of the pump. A drain with a pipe or wooden box leading to the ; lowest tank serves to draw off the water when repairs or cleaning ınks is necessary. There should be draw-off plugs at different ls, so that the water can be drawn off without disturbing the settled . and sand. This can best be removed through a separate plug into ıall tank on the hoisting-cage, and brought to the surface. A notch the top of the tank must also connect with the drain, in order to rt a possible overflow into the next lower tank.

ı.17. *Pump Supports.* The foundations of Cornish plunger pumps ated by rods consist of beams or arches built in across the shaft. y have to bear, not only the weight of pumps, with column-pipes water contained in them, but they are also subject to heavy, len strains from water-ram, on which account they should possess, les strength, a certain amount of elasticity, so as to better resist ks.

ı.18. Smaller pumps can generally have their foundations sup- ed directly by the shaft timbering, the load being distributed over ral sets. Very small pumps are only bolted to the sets themselves,

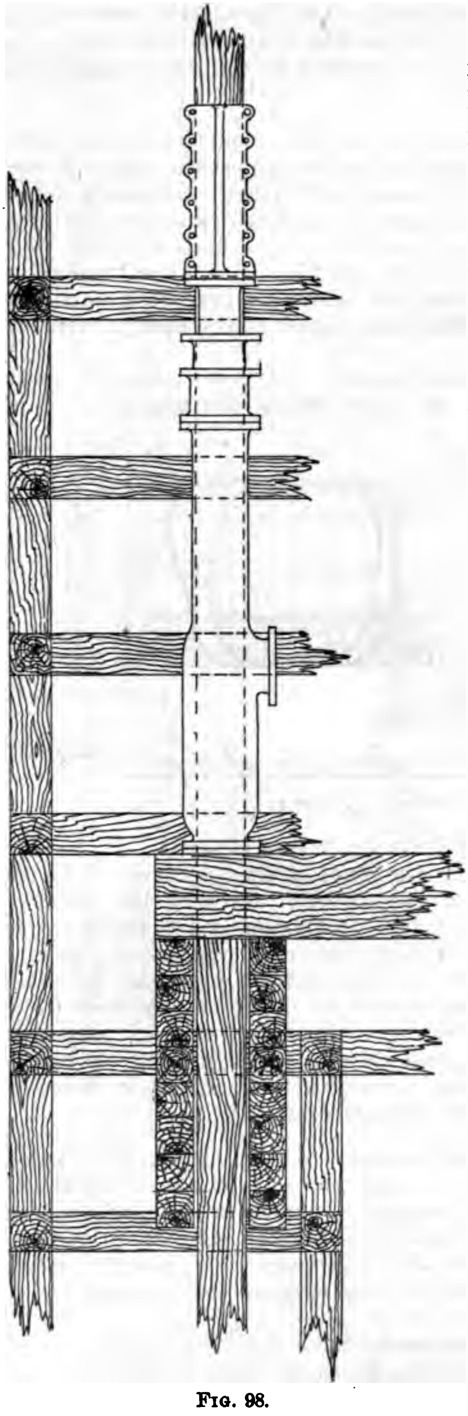

FIG. 98.

being provided with lugs for this purpose. For large pumps, it is always best to rest the supports independently on solid ground, outside of the shaft timbering. In most cases, the supports consist of wooden or wrought-iron beams or trusses. Cast-iron girders or arches are not so good. These may be used, however, if a pedestal of a more elastic material be placed between them and the pump. Where the nature of the ground admits of it, beam supports are preferred, on account of greater simplicity. Masonry, cast-iron, or wooden arches are sometimes used in slaty formations, or where the ground is liable to crumble away under the vertical pressure of beams or trusses, the arch supporting the ground by its principally lateral pressure. Whether beams or arches be used, the excavations for the ends or counterforts should be cut and broken out by hand, not blasted, so as not to shatter the ground too much.

2.4.19. Pump supports of wood are generally used on this coast. The simplest support consists of a pile of beams, like that shown in Fig. 94, built across the shaft. They should be firmly supported and wedged in at the ends, to prevent their displacement. A cross-beam, usually extending into the tank-station, affords ample bearing-surface for both the pump and base of clack-chambers. A simple arrangement like the foregoing can be used where a single line of plungers is offset from the side of the rod, as shown in the plan. Where pumps are placed at opposite sides of the rod, two piles of beams are often used, as in Figs. 98 and 95, to allow the rod to pass between them. Where the

space at the side away from the tank-station is scant, the foundation beams are sometimes placed at an angle, as shown in plan in Fig. 99. In some cases, where good supporting-ground cannot be obtained close to the shaft, the main foundation beams have to be of considerable length, and might thereby become too elastic. In such cases, braces can be thrown in as in Fig. 100, or the beam can be constructed as a truss, like Fig. 101.

2.4.20. Sometimes the pumps are only held on the foundation by their own weight and the pressure of the water-columns. This admits

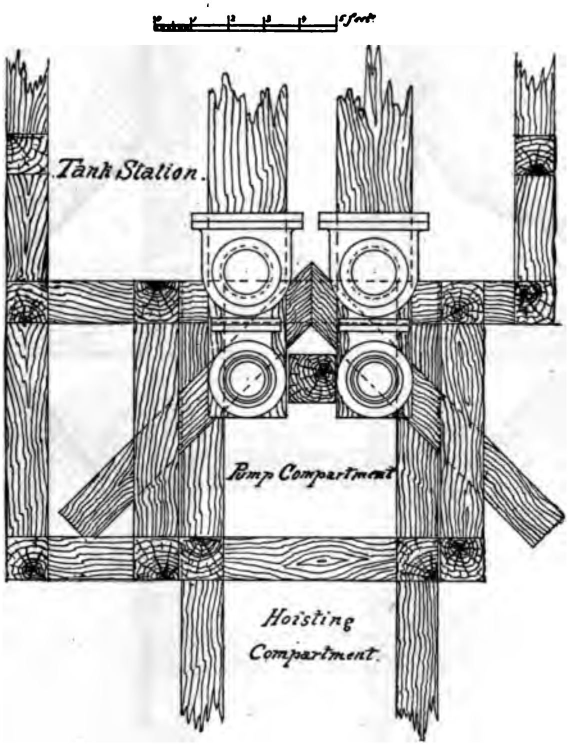

FIG. 99.

of shifting them more readily, to keep them in line if the shaft be in moving ground. It is always best, however, to bolt or clamp the pumps to the foundation. The upper part of the pump-barrel is usually held to the shaft timbering by clamps or strap-bolts, to prevent its lateral displacement.

2.4.21. *Arrangement of Pump-Stations.* Excavations for tanks, like those for balance-bobs, should always extend in a direction opposite to that in which the hoisting-compartments are located. This disposition leaves the ground around the shaft in the best supported condition.

2.4.22. Pump-compartments of timbered shafts, particularly for a double line of pumps, are rarely large enough, without increasing their size at the stations, to admit of such an installation of pumps as to give accessibility to every part, and also leave room in the shaft for lowering

or raising parts of the underground machinery, or for running a cage. The pump-shafts are, therefore, generally enlarged at the pump-station, as in Fig. 99.

2.4.23. *Admissible Lift and Plunger Speed.* The Cornish type of plunger pump is rarely used for lifts above 250′. About 200′ is the usual lift allowed. Lifts of 400′ and 500′ occasionally occur, but with

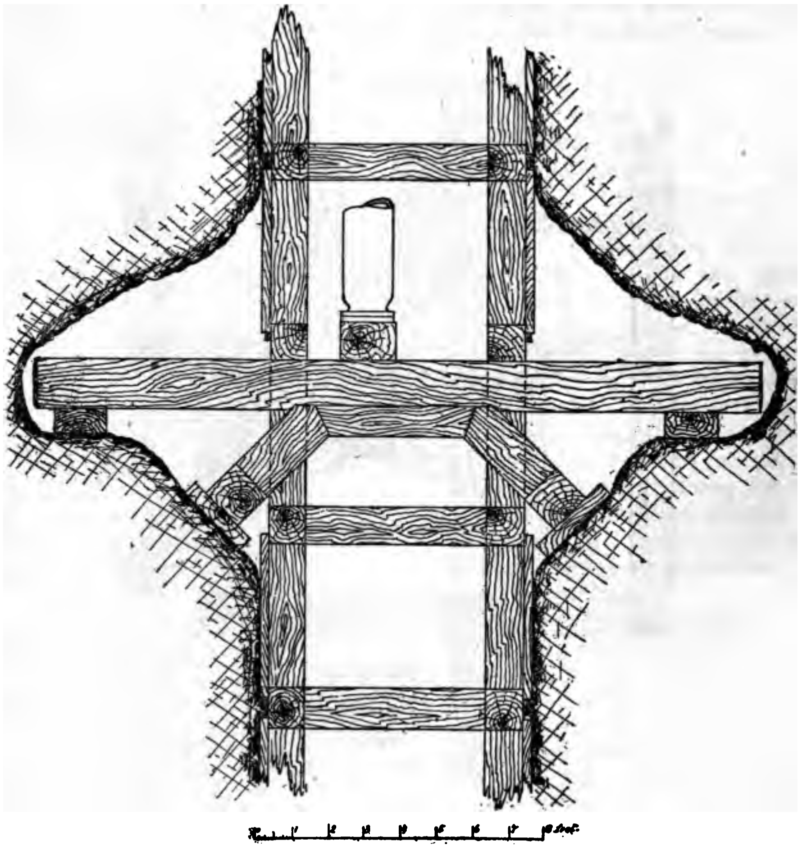

FIG. 100.

such the pumps can operate only at a very much reduced speed, and require, therefore, to be of larger size to handle a given quantity of water. The greater the lift, the slower must the pumps run to avoid too severe shocks. Great length of the pumprod and column-pipes also reduces the admissible number of strokes. (See 2.2.01.) For this reason, inclined pumps cannot be run as fast against the same head as pumps of the same size in a vertical shaft. (See 1.2.38.) The longer the stroke, on the other hand, the greater is the admissible plunger speed. Cornish plunger pumps are usually so placed that the water will run into and almost fill them by gravity. The height above sea-level has, therefore, less influence on the working of Cornish plungers than on that of lift pumps.

2.4.24. *Relative Size of a Series of Plungers.* If the water must all ɜ lifted from the sump of a deep mine, requiring several superposed ts of pumps, the plungers should properly increase in size as they are ɜarer the bottom, to make up for the decreased length of stroke result-g from the elasticity of the pumprod. Generally, however, the pumps :e all made of the same size, so that the parts will be interchangeable.

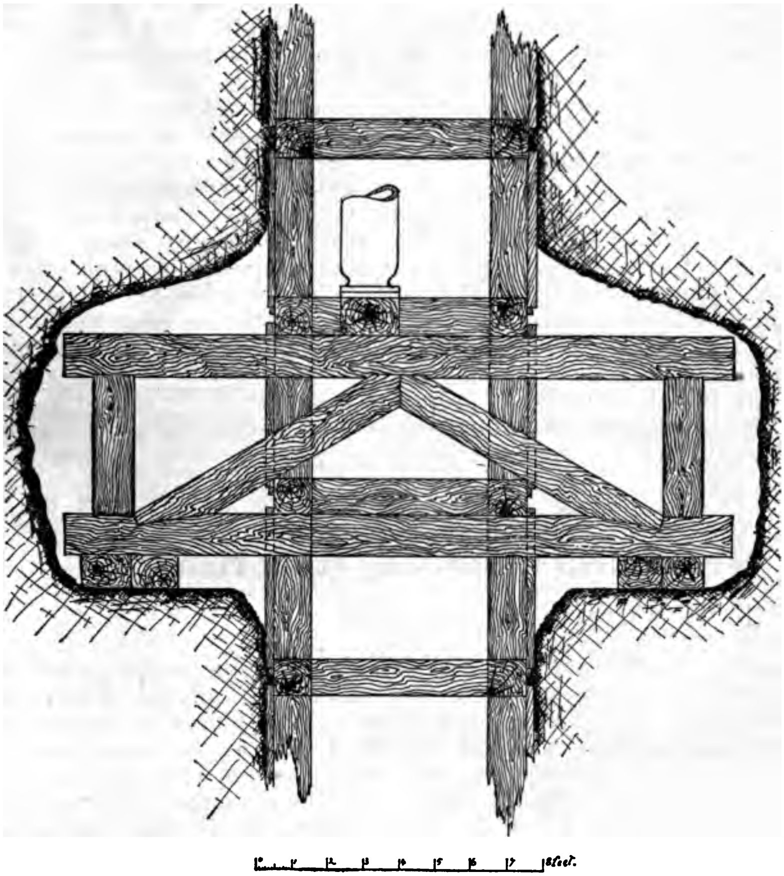

FIG. 101.

But, since plungers and stuffing-boxes are not very liable to breakage, these could be made of the proper sizes, and the valves, valve-chambers, and barrels of all the pumps interchangeable. Where water issues at different levels, the aim should be to adapt the sizes of the corresponding pumps to the water to be handled by them.

2.4.25. Plunger pumps are much more subject to breakage than lift pumps, and extra parts liable to be broken, such as clack-chambers and pump-barrels, should be kept on hand where severe service is required of the pumps. Such parts, as was stated before, are now often made of steel.

2.4.26. Before placing pumps in a shaft, a careful survey of it should be made, in order to determine if it is crooked or twisted out of line, and

the relative position in plan of the different sections should then be drawn on paper and compared with the desired arrangement of pumps, in order to see if sufficient space is available for installing them. After pumps, rods, and pipes are in place, they should be kept carefully in line.

2.4.27. It is desirable, particularly in deep mines, to have space in the pump-compartment for running a small cage, in order to enable the pump-men to reach rapidly any point of the shaft. The ladders which are required in every mine are also placed in the pump-compartment. The space allowed for the cage should be large enough to admit of lowering the largest parts of the underground machinery. As the rods and column-pipes, with their guides and stays, take up a considerable portion of the shaft area, the compartments intended for Cornish pumps require to be of large size. In pumping-plants for moderate depth and capacity, the heavy parts are generally lowered by chain-blocks, or by winches, operated by hand. These winches are also often used for raising and lowering the sinking-pumps, and must be of ample strength for the purpose. Sometimes, however, hand winches for the sinking-pumps are located in the shaft near the top of the discharge-column.

2.4.28. Hand winches are too slow for the largest Cornish plants, and with these regular pump-hoists, geared in a large ratio, so as to be able to lift or lower heavy loads, are installed at the surface. These are then generally used also for running a cage in the pump-compartment.

CHAPTER V.

Power-Plants for Operating Pumps Through Rods.

STEAM ENGINES.

2.5.01. The steam engines for operating mining pumps by means of rods will, for want of a better generic name, be simply called rod-pumping engines in the course of this article. They may be rotative, non-rotative, or geared. The non-rotative types can be either direct- or indirect-acting. Direct-acting engines are those in which the piston-rod is in line with and forms an extension of the pumprod. Indirect-acting engines are those in which the piston-rod moves the pumprod through the medium of a beam or bob, as in Fig. 102 or 103.

2.5.02. Rod-pumping engines are now rarely made direct-acting, because the cylinder then obstructs the mouth of the shaft. Where a beam is used in modern mine pump engines it is usually placed below the cylinders, because in this manner the top of the shaft can be kept clear.

2.5.03. Large cylinders of pump engines are best placed in a vertical position, because then the heavy piston will not wear the cylinder on one side, as in the horizontal engines.

2.5.04. *Non-Rotative Engines.* It seems proper to consider the non-rotative engines first, as they are the oldest type.

2.5.05. During the sinking of a shaft in water-bearing ground the work to be done by the pump engines changes, not only according to increase of depth, but also by the opening-up of new bodies of water.

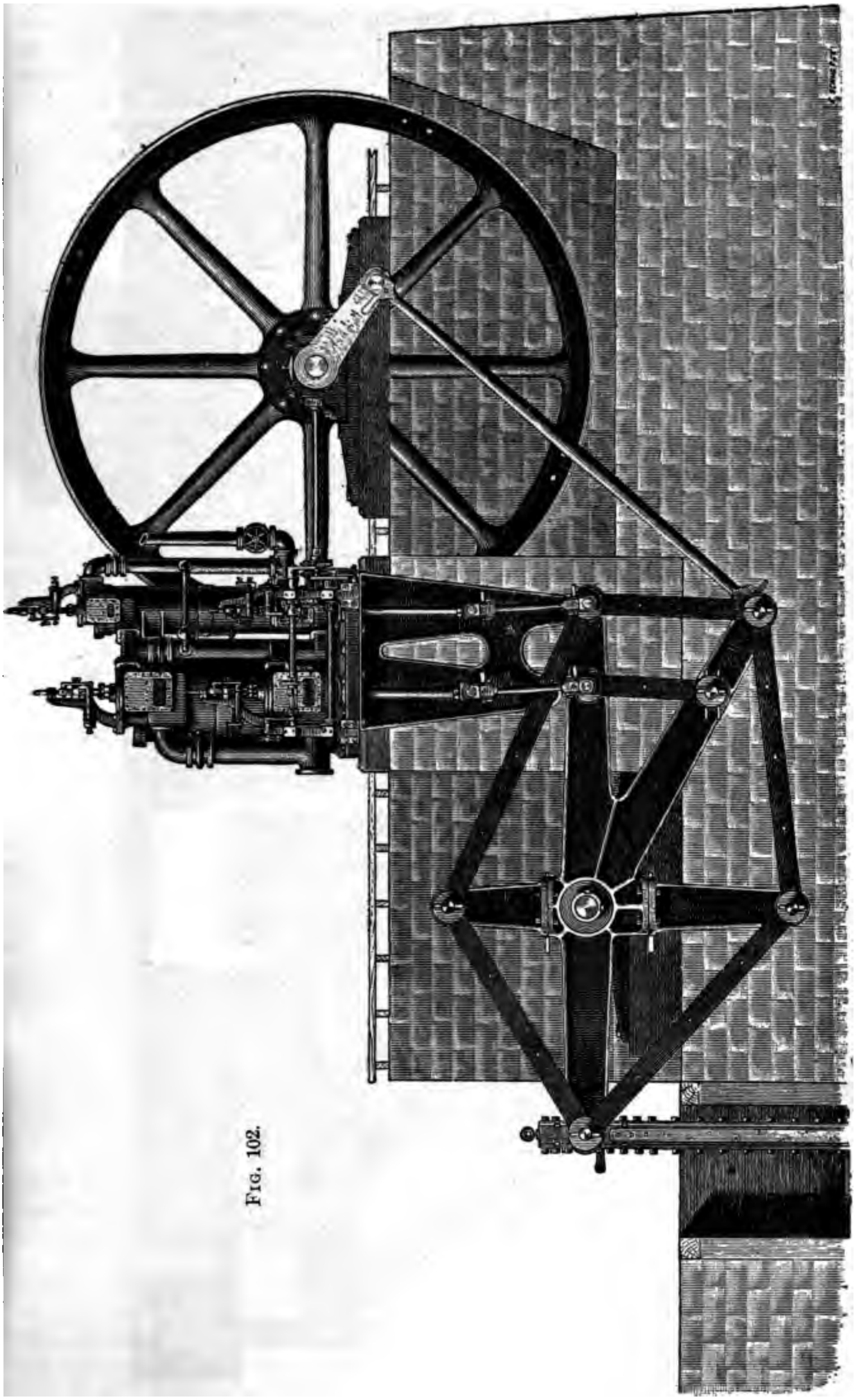

Fig. 102.

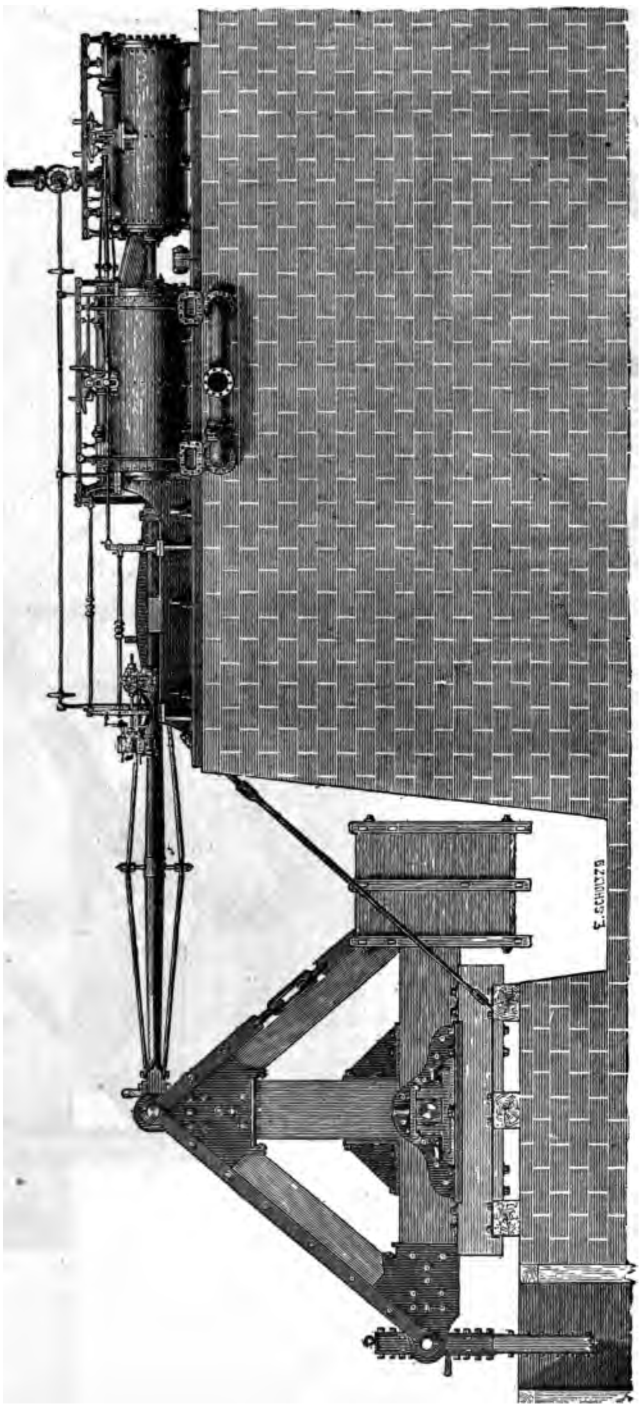

Fig. 103.

The old single-acting Cornish engine and the double-acting engines of the Ehrhardt type, both of which work with variable pauses at the end of the stroke, admit of considerable variation in quantity of water pumped by changing the duration of the pauses between the strokes. Such pauses are useful also in affording time for the pump-valves to seat before the return-stroke is started. These engines are, however,

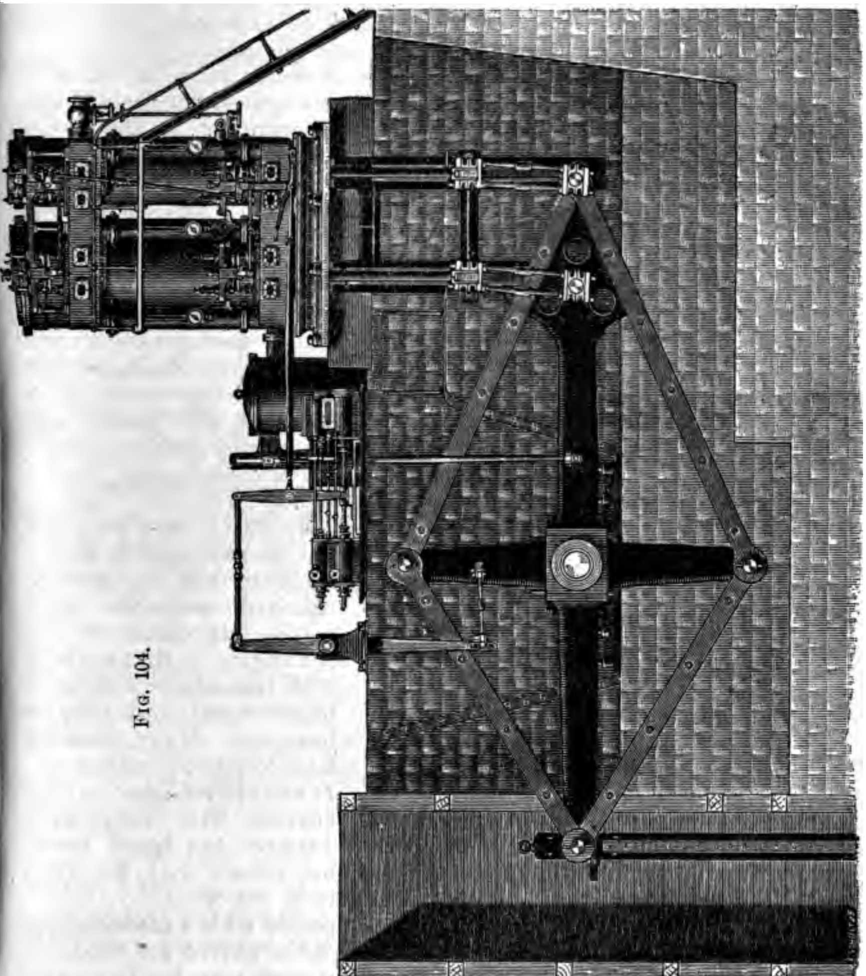

FIG. 104.

even when compounded, not well adapted for sinking, because the engine work during each single stroke can be varied only within comparatively narrow limits.

2.5.06. The only engines of the non-rotative class which have been applied to the Cornish or rod-pumping system in our mines are engines with Davie valve-gear, many examples of which are to be found on the Comstock. Fig. 103 illustrates the Davie engine with bob, examples of which once operated at the C. & C. shaft, the Gould & Curry, and Hale & Norcross at Virginia City, Nev. The Belcher and Overman

vertical-beam engines are shown in Fig. 104. The Lady Washington, Lady Bryan, and Alta mines have also had such engines in operation. The steam distribution in these engines is either by slide- or by puppet-valves, controlled by the combined action of a small steam cylinder and that of the main engine itself. The steam is, however, not permitted to act by simple expansion, but is wire-drawn to a great extent. In order to secure the requisite degree of uniformity of pressure during the stroke, and at the same time some of the benefits of expansion, the Davie engines were usually constructed as compound engines.

2.5.07. These engines admit of a somewhat wider range of variation of work per stroke than the older non-rotative engines, but their degree of economy in the use of fuel is considerably behind what might to-day be expected of a first-class pumping engine of the rotative type.

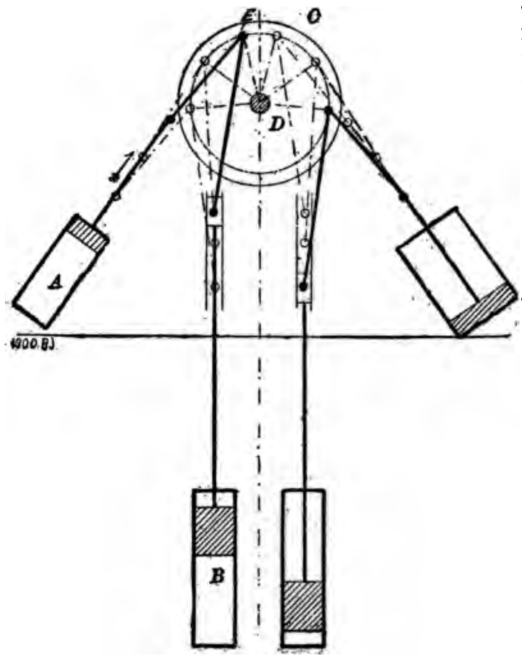

FIG. 105.

2.5.08. In all non-rotative engines, the point at which the stroke is completed is uncertain, on which account they have to be operated with a very large amount of clearance, entailing a considerable waste of steam.

2.5.09. In case the pump-rod breaks near the surface the load will be suddenly removed and the heavy masses disconnected from the engine, so that the latter will immediately attain a higher speed, and strike the bumpers. Many breakages have occurred in this way. It was claimed for the Davie engines that they would automatically shut off their own steam whenever the speed became greater than a given rate; but experience has shown that the Davie valve-gear was no safeguard against accidents of this kind.

2.5.10. Non-rotative engines require to operate with a more uniform pressure during the stroke when the masses to be moved are moderate, as will be the case when a shaft has not been sunk very far, than when the masses are great, as in a deep shaft, where a greater initial pressure can be allowed to accelerate the heavy masses. In other words, the steam should be cut off latest when the work is least, and vice versa. The only way to reconcile these contradictory conditions is by using a very low boiler pressure at first, and greatly increasing it as the shaft goes down. This, however, would be impracticable beyond very narrow limits of pressure. In the Davie engines these defects are corrected to a certain degree by wire-drawing the steam.

2.5.11. In order to enable non-rotative engines to utilize expansion

re perfectly, Davie has more recently arranged some of his engines h beams that work the pumps with variable leverage, as shown in . 105. The lever arm stands about normal to the line of motion at beginning of the pump-stroke, so that, as it swings through a con- erable arc, the effective or projected leverage is much reduced at the . of the stroke, thereby causing the moment of the pump-resistance correspond at each point more nearly with the change of pressure on engine-piston. As the engine is double-acting, two single-acting, ositely reciprocating pumps are necessarily coupled up in this

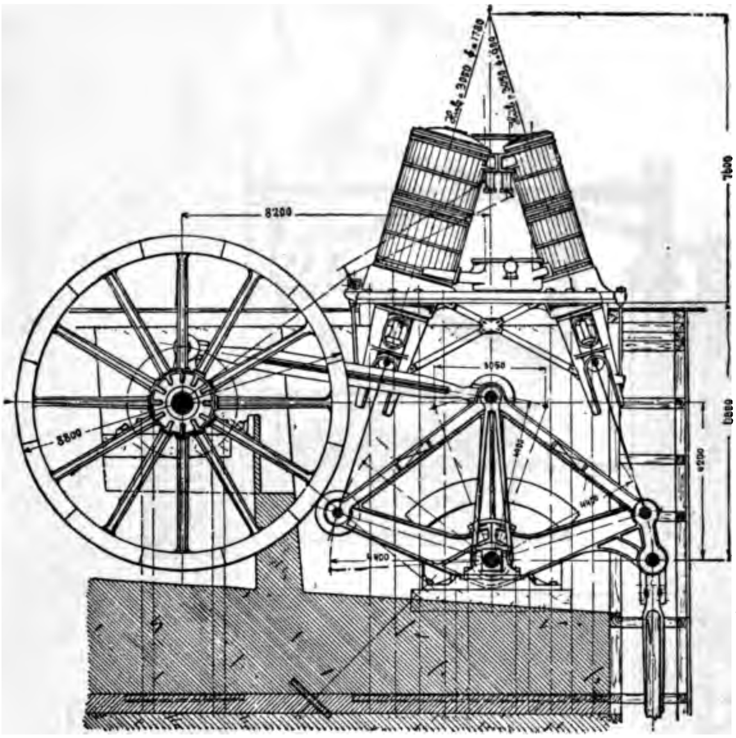

FIG. 106.

nner. The non-rotative principle is not being applied much in ent rod steam-pumping-plants, and it does not seem probable that ny more engines of this class will be constructed for mines on this st.

.5.12. *Rotative Engines.* The modern forms of these are the most fect types of rod-pumping engines. They admit of economical steam tribution by comparatively simple valve-gear. They can be operated higher speeds; on which account they can be made of smaller size, l the work per single stroke can be varied in much wider limits than be done with the non-rotative engines. The last-named quality kes them well adapted for sinking purposes. On account of these antages, most of the recently built rod-pumping engines, both in erica and in Europe, have, notwithstanding their greater cost, been

constructed on the rotative principle. An incidental advantage of the rotative engine is that, in case the pumprod breaks near the upper end, and the load is thereby suddenly removed from the engine, the latter will require time to accelerate the mass of the flywheel and run away,

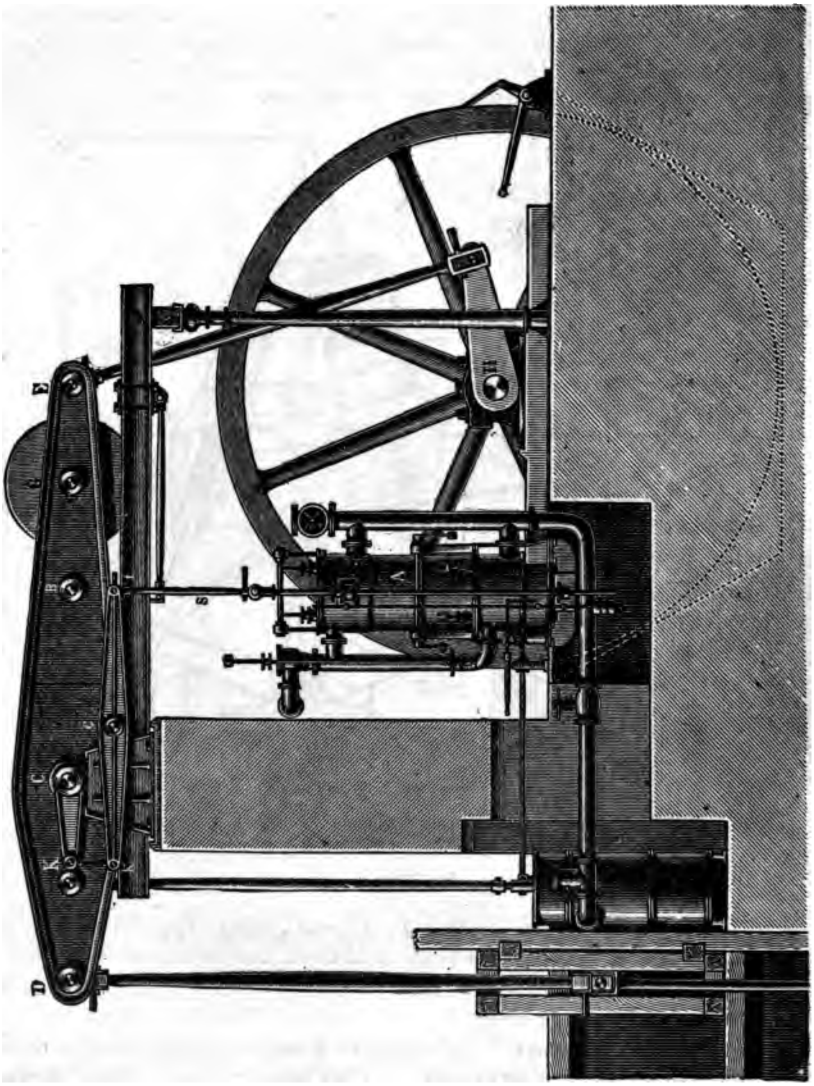

Fig. 107.

so that the attendant has a chance to close the throttle. Governors which automatically close the throttle or throw a brake onto the fly-wheel as soon as the speed exceeds a certain limit, can also be easily applied.

2.5.13. Fig. 102 illustrates the beam pump engine at the New Almaden Quicksilver Mine, near San José. Fig. 106 gives the arrange-

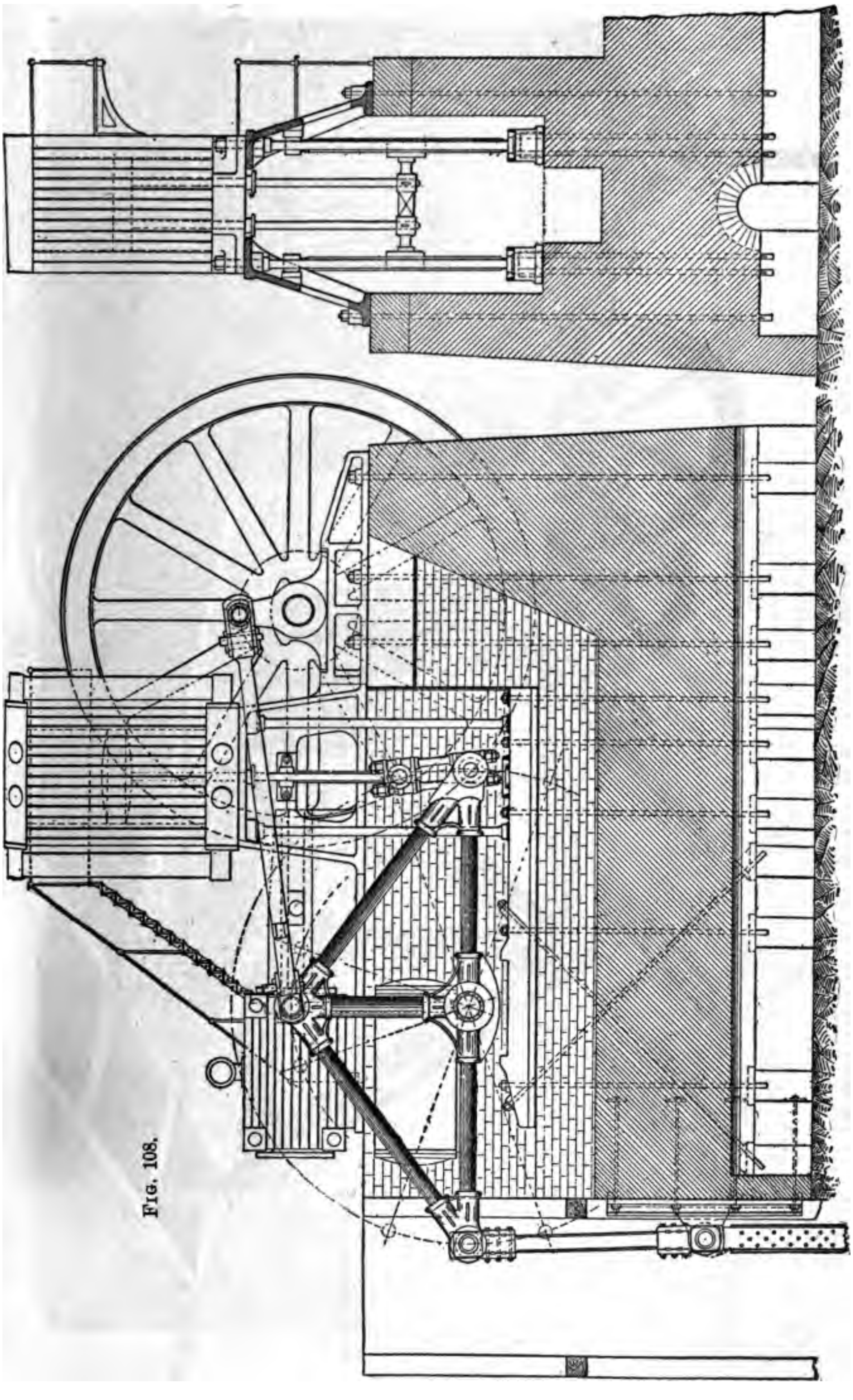

Fig. 108.

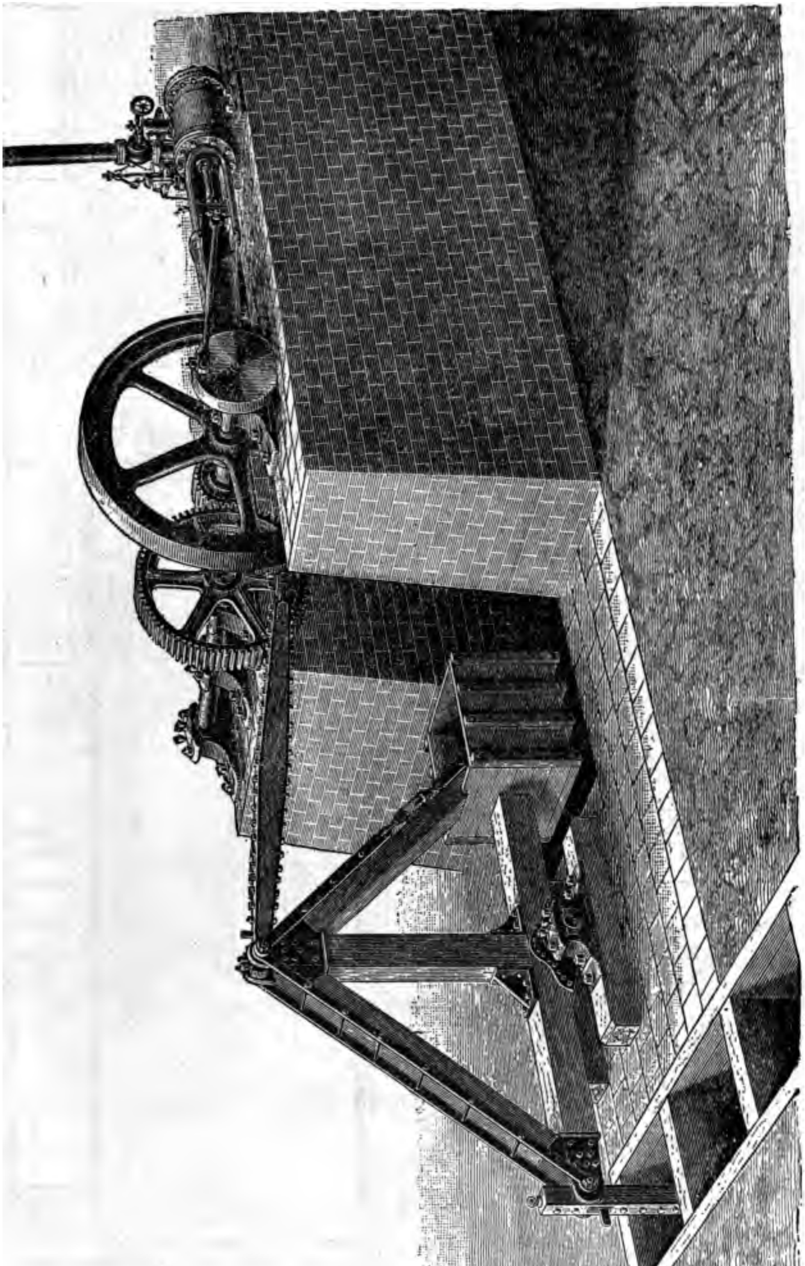

FIG. 109.

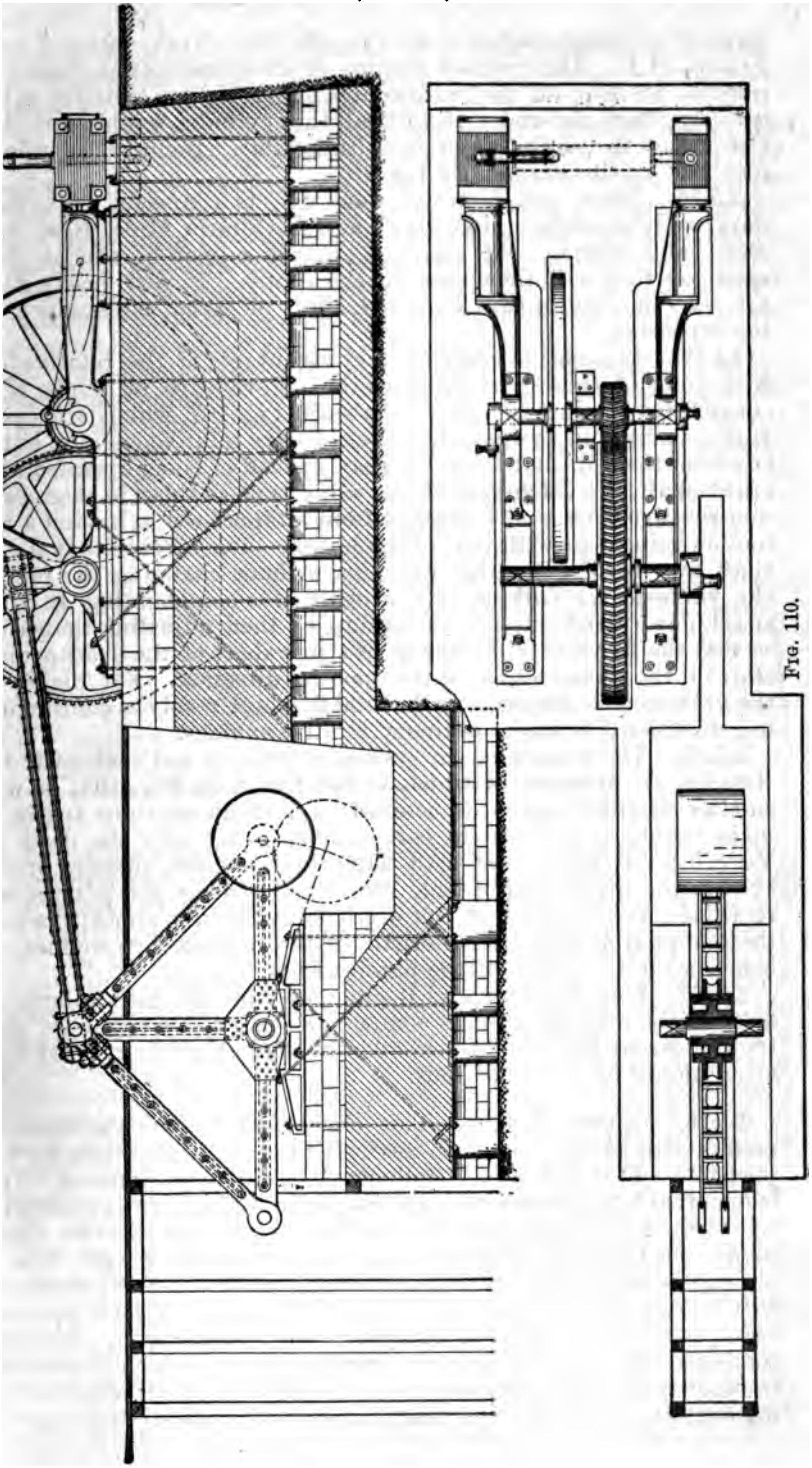

FIG. 110.

ment of the pump engine at the Ontario Mine, Utah, designed by W. R. Eckart, M.E. The inclined position of the cylinders was chosen to take some of the load off the beam-center by letting one cylinder take hold directly above the rod. If vertical, this cylinder would have to come right over the shaft, which is objectionable. Inclined cylinders were first used in this manner by Leavitt.

2.5.14. There are, however, some defects connected with the ordinary rotative engines, like those at the Ontario Mine, New Almaden Mine, and others. This class of engines cannot be run at very low speed, as they will then stop on the center. If very heavy flywheels are used in order to gain some reduction in speed, the engines become too expensive.

2.5.15. In order to combine the advantages of the rotative engines with some of those pertaining to the non-rotative principle, Kley has constructed engines like those shown in Fig. 107, which are connected with a crank and flywheel, like the ordinary rotative engines, but differing from these in that the valve-gear, instead of being operated from the crank-shaft, is a latch-gear of the same type as those in engines of the non-rotative class, and is worked from a tappet-rod a, having a reduced motion coincident with that of the piston. The effect is that the crank-shaft may revolve in either direction without changing the function of the valve-gear. This quality is utilized when running at very low speed, down to one stroke per minute, by then adjusting the valve-gear so that the flywheel will come to rest just short of the dead points, and start on the return-stroke in the opposite direction. For higher speeds the valve-gear is adjusted so that the flywheel revolves continuously in one direction like in the ordinary rotative engines.

2.5.16. The most modern system of rotative rod engines is that of Regnier, an example of which is illustrated in Fig. 108, in which a smaller auxiliary engine is coupled to a crank at right angles to the main crank, so as to aid in carrying the latter over the dead points. Very light flywheels are used with these engines, thereby producing, even at the highest admissible number of strokes per minute, a much retarded rotative speed at the dead points, giving almost the pause of the pumprod motion characteristic of the non-rotative engines, and so beneficial to the action of the pump-valves.

2.5.17. Both the Kley and Regnier systems are, particularly for the larger sizes, usually built as compound condensing engines. As such, they represent the highest perfection in steam machinery used for operating pumps by means of rods.

2.5.18. *Geared Engines.* This class of engines is the most widely used on this coast for operating Cornish pumps, particularly for sinking purposes. Figs. 109 and 110 illustrate usual arrangements. The bob is operated by a pitman from a crank, as in Fig. 110, or a crankpin in the side of the gear, which is driven from the engine, as in Fig. 109. In larger plants, the crankpin is usually carried between two gears. The crankpin can be set at different radii, by which means the pump-stroke can be reduced, which gives to the leverage of the engine a greater proportional value, making it capable of pumping from greater depth. This feature, combined with the variability of work per stroke, which is more limited in other systems, makes this class of engines excel all other rod-pumping engines in the range of pumping-depth for which the same engine

may be used, and, therefore, particularly fits them for sinking purposes. The decreased capacity due to reduction of pump-stroke can be partially made up by a greater number of strokes.

2.5.19. The capacity of the engine may be still further varied by changing the proportions of gearing. Other advantages of this class of engines are that they are cheap, and when no longer required can often be readily disposed of, on account of the facility with which they can be altered to adapt them to other conditions or other work than pumping. It is also possible to arrange them with reels or drums to carry a cable, and to fit them with means to throw the drum into gear and disconnect the pumps, so that the engines can be made to serve as a pump-hoist for sinking work and lowering parts of machinery in the shaft.

2.5.20. An objectionable feature of the geared engines is, that as the engine work per pump-stroke is uniform they will have their greatest speed when the resistance work of the pumps is least; that is, at the dead points. This causes greater strains in the pumprods than with

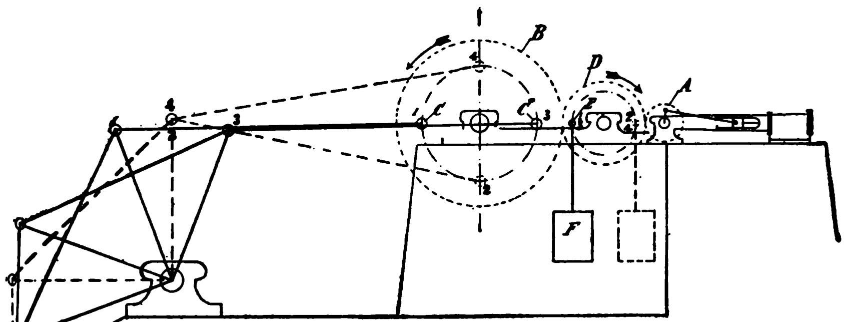

Fig. 111.

the other rotative engines, while at speeds admissible with the latter the action of the pump-valves will be so tardy that shocks will result. The number of strokes that can be allowed with existing types of geared engines is, therefore, appreciably less than with any of the other rotative systems operating pumps under the same conditions, and the geared engines and pumps operated by them have, therefore, to be made larger than if the dead points of the pump-stroke could be turned slowly. Operating a double line of pumprods connected to crankpins at right angles would reduce the acceleration at the dead points, but would not entirely eliminate it; besides, such an arrangement would rarely commend itself, on account of complication in the pump-shaft. To cause the engine to do other work besides pumping, such as air-compression, which would be a maximum at the end of the pump-stroke, is also generally impracticable.

2.5.21. A more perfect method is to cause the engine to perform and store up, near the dead points of the pump-stroke, other work besides pumping, such as raising a weight, and to permit such stored-up work to assist in overcoming the resistance of the pumps near the middle of their stroke. An arrangement for carrying out this idea was patented by Charles Bridges in 1883. The principle of the device, though probably never applied to mining pumps, is shown so applied in Fig. 111. Between the driving-pinion *A* on the motor-shaft, and the driven gear *B*, carrying the pin *C* for operating the pumps by the pitman and bob,

there is interposed a third gear D, having half as many teeth as the large gear B, and, therefore, making two revolutions to one of B; a pin E is fixed in the side of gear D, and supports a weight F at its maximum leverage, when the pump crankpin C is at either of its dead points. The direction of rotation must then be such that weight F will be lifted and cause resistance to the engine when that of the pump is lacking. When the pump is at mid-stroke, the pump gear B will have made one quarter of a revolution, and the intermediate gear D will have made one half of a revolution, so that the weight F now descending on the opposite side of the center of D, aids in overcoming the resistance of the pump.

2.5.22. With a pumping-plant of any size, the disturbing effect of the moving mass of the weight F would be very great, and in such cases it is suggested that a piston under a constant pressure of air or steam would be a better contrivance.

2.5.23. The simplest plan would seem to be to automatically vary the steam admission during each stroke, down to zero, or nearly zero, near the dead point. In this manner the engine could be adjusted so as to run slowest when the pumps are near the ends of their stroke, thereby permitting the valve to come to rest quietly, even at an increased number of strokes.

2.5.24. The geared pump engine deserves more consideration toward its improvement than has been accorded to it where rod-pumping is the method to be used. The many existing examples on this coast are mostly of very crude and imperfect design. By arrangements which operate like those described in the three preceding paragraphs, the engines can be made smaller, corresponding to the admissible increase of pump-speed, and the saving in cost could be applied to obtain means for securing greater economy in the use of steam, such as compounding, steam-jacketing, or condensing. More perfect and better constructed gears than those on most of the existing engines of this class are also desirable.

2.5.25. *Remarks.* An important matter in connection with pumping-engines at the surface is their location with reference to the shaft. In general, it is most advantageous to place the engine at that side of the shaft which is farthest from the hoisting-compartments, as in Fig. 112, because then the space around the shaft will be least obstructed. In inclines, however, the pump engines must be placed in a vertical plane parallel to the incline; that is, either on the same or the opposite side of the shaft on which the hoisting engine is located. The nature of the ground and kind of foundation obtainable around the mouth of the shaft may influence the general design of the engine. It may also be influenced by the cost of fuel, the suitability and quantity of water obtainable for condensation purposes. The depth from which water is finally to be raised, and the limit of speed depending thereon, supposing the quantity of water to be approximately known, are the chief elements in fixing upon the size of the engine. Where economy is an object, compounding and steam-jacketing should be resorted to. At high altitudes condensation will be of less advantage than near to sea-level. In case of water which is not suitable for feeding boilers, surface condensation may be of advantage.

2.5.26. As has been stated, a mine requiring pumping should also be

equipped with bailing arrangements of the capacity of the pumps, so that, when these or the pump engine requires repairs, the water can be controlled. Where the pumping-plant is of large capacity, geared hoists are generally too slow for handling the water and at the same time taking care of the other hoisting operations. For such cases, large direct-acting hoists should be used which can bring the tanks to the surface rapidly.

2.5.27. The boilers supplying steam to a pump engine should be independent of those from which the hoisting engines are fed, because the intermittent work of the latter causes changes in the steam pressure, which would seriously affect the speed of the pump engine.

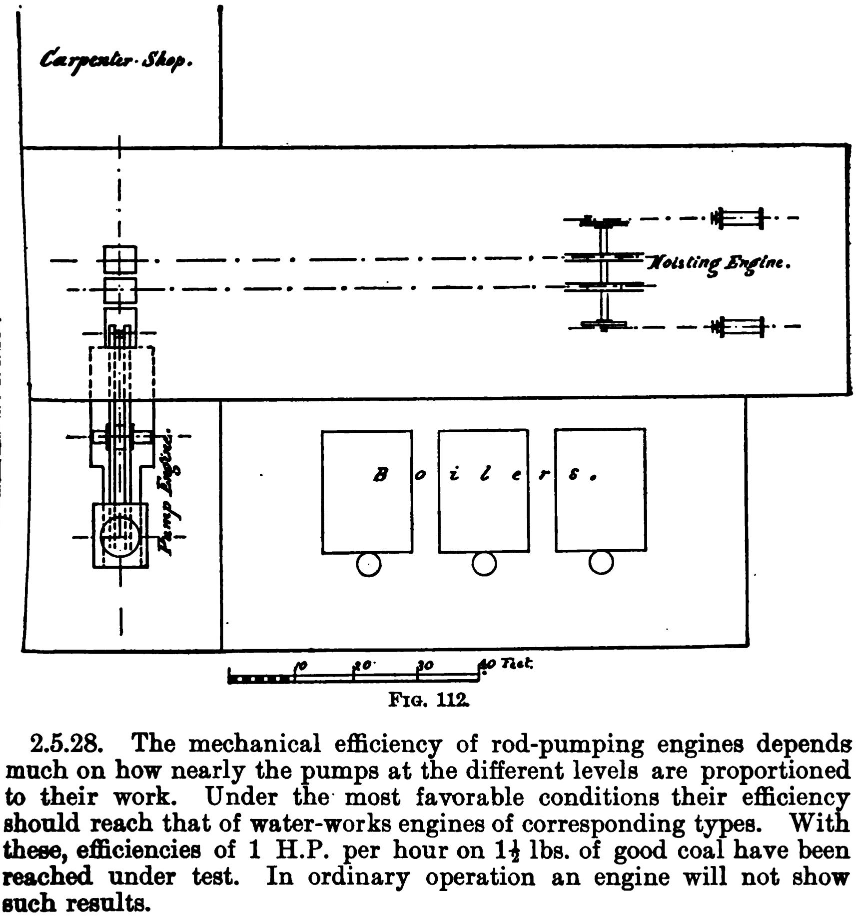

FIG. 112.

2.5.28. The mechanical efficiency of rod-pumping engines depends much on how nearly the pumps at the different levels are proportioned to their work. Under the most favorable conditions their efficiency should reach that of water-works engines of corresponding types. With these, efficiencies of 1 H.P. per hour on 1½ lbs. of good coal have been reached under test. In ordinary operation an engine will not show such results.

2.5.29. *Hydraulic Motors for Pumprods.* These may be either waterwheels or reciprocating-piston engines. Of the former it is only necessary to mention one type, the tangential waterwheel, of which the Pelton, Dodd, and Knight wheels are representatives. Reciprocating hydraulic engines have but a limited application on this coast for operating pumps by means of rods. The ones best known are those designed and constructed by Mr. Knight, of Sutter Creek, California. Neither

tangential wheels nor reciprocating engines are suitable for utilizing very low heads of water. These would hardly ever find application for direct pumping, the instances where they can be utilized generally requiring comparatively long transmission by compressed air or electricity.

2.5.30. Cases sometimes occur when it is not easy to decide whether steam or water is the most economical or reliable means of operating

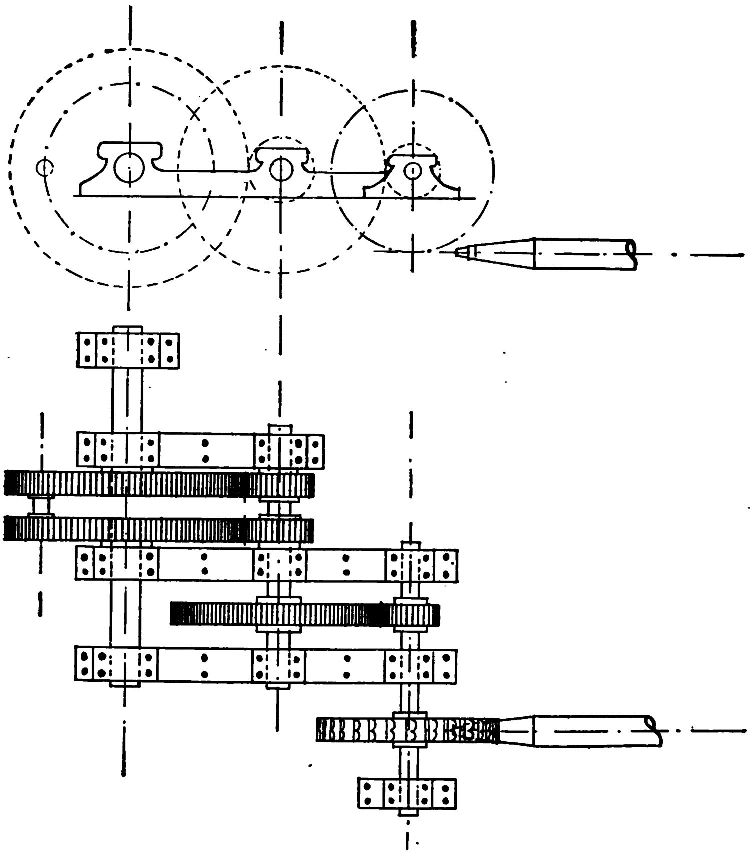

FIG. 113.

the pumps and other machinery at a mine. The cost of installation, the operating expenses, and the permanence of fuel or water supply, or that of its cost, must be considered and compared. It is also necessary to find out if the water supply will fall off appreciably during the latter part of the season.

2.5.31. In using water-power it is generally necessary to provide for stoppage of supply, due to breaks in ditches or pipes, by having a relay of steam-power, at least for the hoisting machinery, which should be of such a capacity that the water in the mine can be controlled entirely by bailing. The steam-relay is also needed where the water supply becomes short in the fall or freezes up in winter.

2.5.32. *Waterwheels.* Those employed for working Cornish pumps are arranged to drive these by means of gearing similar to that used with geared pump engines, the pump-bob receiving motion from a crankpin in the side of the driven gear, as in the geared steam pumping-plant shown in Fig. 109. Gearing is necessary because the pressure usually employed causes the wheel to make too great a number of revolutions, even with the largest practicable wheel diameter, to admit of directly driving the pump-bob. Sometimes even compound gearing is required to obtain the necessary reduction in speed, as in Fig. 113.

2.5.33. In order to utilize the power in the water to the best advantage, waterwheels should run at a fixed number of revolutions. The capacity of the pumps can, therefore, only be changed, aside from changing the pumps themselves, either by varying the radius at which the crankpin acts, or by changing the gearing. Any of these will require corresponding changes in the waterwheel nozzles, to adapt the power to the altered resistance. Increase in depth, the quantity of water remaining constant, must be met by an increase in size or number of nozzles, or by means for varying their discharge.

2.5.34. It is well to have a number of nozzles to the waterwheel, with a gate to each nozzle. With such an arrangement, the power can be adjusted and varied by regulating one of the nozzles, the choking-off amounting then to reduction of efficiency only of the nozzle affected, that of the others remaining undiminished. Fig. 114 illustrates an arrangement of this kind.

2.5.35. Fig. 115 illustrates a nozzle, affording a variable cross-section of jet, designed and patented by Mr. A. Chavanne, of Grass Valley. It consists essentially of an ordinary nozzle, having an opening suitable for the maximum discharge required, the reduction of cross-section being accomplished by the solid mandrel *D*, which is made with successive abruptly increasing diameters. By pushing the mandrel forward in the nozzle by means of the lever mechanism shown, the area of the opening is reduced by an amount equal to the area of that part of the mandrel which is at that moment within the nozzle-opening, the resulting jet being thereby caused to assume an annular section, of which the inner diameter can be increased so as to reduce the total area. If the mandrel were simply tapered instead of being made to increase by steps, the issuing water would cling to the surface of the mandrel, so as to be partly deflected, thereby causing a disturbed jet. Although the efficiency of the annular jets decreases with the increase of the inner diameter, on account of the greater proportion of wetted perimeter, this reduction is not of so vital importance as to counterbalance the other advantages of the Chavanne nozzle, chief of which are its simplicity and ease of manipulation by either hand or governor.

2.5.36. Waterwheels applied to operating pumps from cranks have the same defect as the geared steam engines; that is, they speed-up near the dead points of the pump-stroke, which results in tardy closing of the valves, and prevents higher speed, on account of the shocks that otherwise occur. What has been suggested in relation to remedying this fault in geared steam pump engines (2.5.21), also has application to waterwheels, with the exception of variation of power supply during each pump-stroke to suit variation of resistance, which would be impracticable with waterwheels.

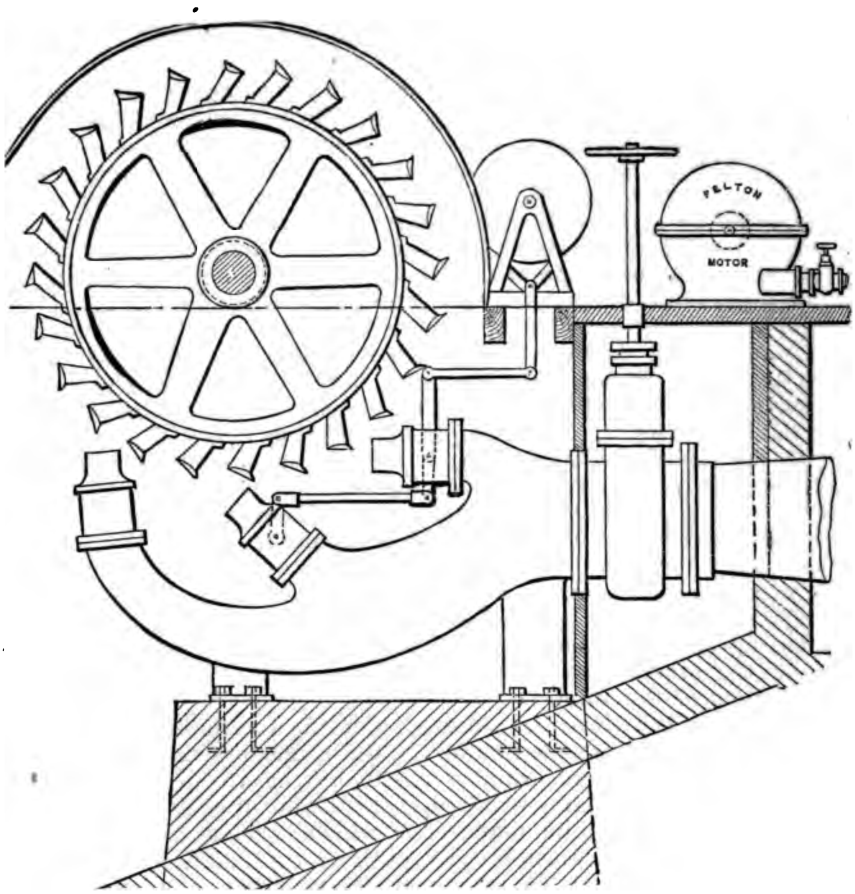

Fig. 114.

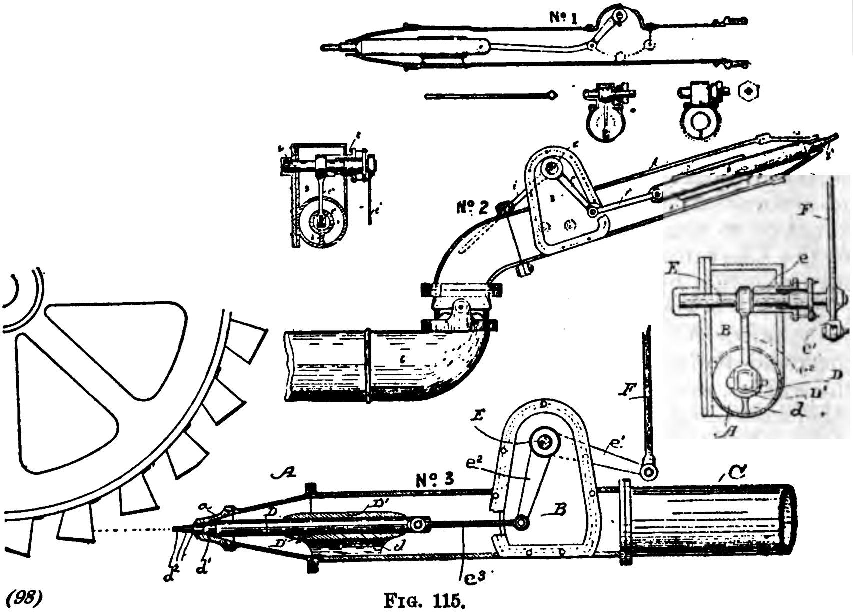

Fig. 115.

2.5.37. *Hydraulic Pumping-Engines.* These are suitable for operting under both high and moderate pressures. For the Cornish sysem, they are arranged either to work the rod direct, or they are

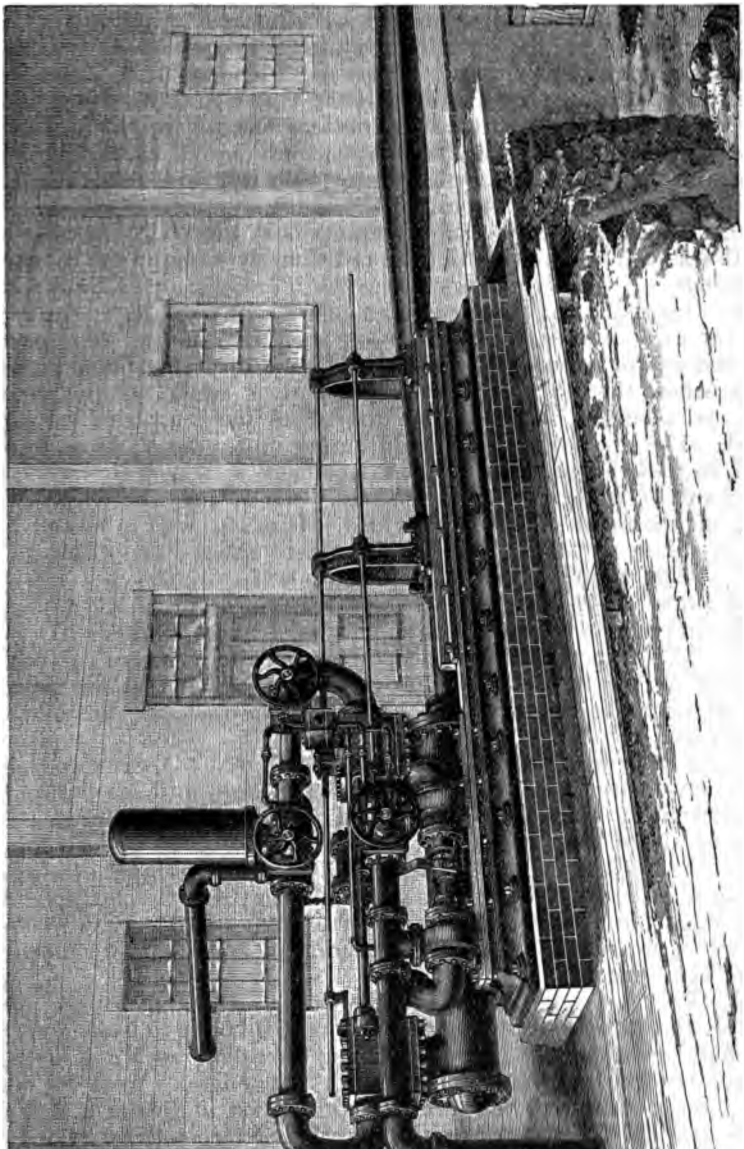

FIG. 116.

onnected to it through beams or bobs, like the non-rotative steam ngines. Like these, also, they are made single- or double-acting. A ype of the latter is shown in Fig. 116. The engine illustrated is work-

ing at the Plumas-Eureka Mine, in Plumas County, and is one of those designed and built by Messrs. Knight & Co., of Sutter Creek, Amador County. The engine is operating under a 720′ head.

2.5.38. The admission of water to, and discharge from main cylinder is performed by flat D-valves moved by an auxiliary cylinder, seen above the main one. This auxiliary cylinder is controlled by a small slide-valve actuated by the upper tappet-rod. The exhaust passes from the main valves through two balanced piston-valves in the short cylinders seen in front just above the main frame. The piston-valves in the exhaust are controlled by the lower tappet-rod, closing slowly after the main piston has reached its maximum velocity, and retarding and cushioning the flow of the water and the heavy pumprods.

2.5.39. Another of these Knight engines is at the Wildman Mine, at Sutter Creek. This takes hold of the rod directly without the intervention of a bob.

2.5.40. Like the non-rotative steam engines, hydraulic engines can operate at any number of strokes below their maximum. The pauses at the end of the stroke can be made of any duration independently of each other, thereby securing almost perfect action of the pump-valves. In addition, it is possible to reduce the length of stroke, if required. The discharge-pipe should empty under water, or be turned upward, so that the pressure of the atmosphere will keep the working-cylinder full of water during the pauses. Air-outlets and drain-cocks to wash out sediment should be provided. It is also well to have relief-valves at different parts of the engine where shocks are liable to be severe. Where plungers are used in the power-cylinder, they are best made of brass or bronze, for the same reasons as in plunger pumps. With piston engines the cylinders should be of brass or lined with it.

2.5.41. It is important that the power-water delivered to the engine be as clean as possible. Ample provisions for settling and screening should therefore be made at the supply-reservoir at the head of the pressure-pipe.

2.5.42. The pressure-pipe should be large, so that the water in it will have a low velocity, because the flow is intermittent and the column of water alternately started and stopped like in a pump-column. The number of times that this can be permitted to occur per minute is limited, and therefore the engine cannot make a great number of strokes. The admissible number of strokes is less than with non-rotative steam engines, particularly for high heads, on account of the great mass of water in the pressure-pipe, which is usually of great length compared to the pressure-head.

2.5.43. For the sake of reducing shocks, air-chambers are often placed on the pipe near the engine. It is still better to use a number of air-chambers along the pipe-line, as has been done by Mr. Knight.

2.5.44. Hydraulic-pressure engines are not generally used for sinking purposes, because the pressure per square inch is constant, and the total pressure on the piston or plunger can therefore only be varied by changing its diameter.

2.5.45. The field for hydraulic-pressure engines as prime-movers at the surface has been much reduced by the much cheaper and more durable high-pressure tangential waterwheels. These are not only cheaper in themselves, but can have much lighter and also smaller

power-mains for the same head, because the flow of water in them is continuous and not intermittent, as in hydraulic engines.

2.5.46. An advantage which the hydraulic engines have over the waterwheel is that they can easily be set up below ground, in which case the discharged power-water is forced up with the mine-water through the column-pipe. The engine need not be larger for this purpose, as the additional water to be raised is balanced by the increase in driving pressure.

2.5.47. By placing the engine thus below in the shaft in the line of the pumprod at the middle of its length, the effect of elasticity of the rod on the stroke of the pumps most distant from the application of power will be much reduced, and the rod system can in such a way be used for greater depths than where the engine is at the surface. Hydraulic engines working pumps direct have also been built by the Risdon Iron Works. Their description will be referred to in the section on direct-driven pumps.

CHAPTER VI.

Operation and Care of Pumps.

2.6.01. *Starting and Adjustment.* Before putting pumps in operation they must first be primed or filled with water, and to make this possible, an escape for the air must be provided by means of cocks located at high points. The manner of priming was described in 1.1.12 and 1.1.13.

2.6.02. In order to adapt the total capacity of a Cornish pumping-plant to the varying water production of a mine, the speed of the pumps must be made adjustable. In geared motors the stroke is also generally made capable of variation, as described in 2.5.18. This was shown in 2.5.33 to be particularly necessary with waterwheels, in which it is not economical to change their speed.

2.6.03. The individual pumps forming a series operated by a rod, will often have to handle quantities of water differing greatly in amount, which amounts again may vary considerably, independently of each other and at different times. Since the relative volume-displacement of the different pumps is fixed by virtue of their attachment to one rod, some of the station-tanks would overflow, while others would be entirely drained and the pumps would draw in air. To provide against overflow the pumps must be speeded up, while those pumps which would then drain their tanks must return to these a portion of the water pumped out, so that the suction-pipe will always be kept covered. To accomplish this the arrangement described in 2.4.13, and illustrated by Fig. 94, is used, in which a float *a* in the tank, on the sinking of the water-level, operates a lever *b*, whereby the cock *c* is opened so as to let water flow from the column-pipe into the tank.

2.6.04. When sinking is suspended and the inflow of water has diminished to a very small amount, it is often better to provide a deep sump, in which the water is allowed to accumulate and from which it is pumped out from time to time.

2.6.05. *Speed of Pumps.* As sinking proceeds and the mine becomes deeper and the masses to be moved greater, the allowable speed becomes less, so that the capacity of the plant is reduced as the depth increases. (See 1.2.38, 2.2.41, and 2.4.24.)

2.6.06. *Lubrication.* The plungers should be kept well greased, the kind of lubricant used depending somewhat upon the temperature of the water in the mine. (See 2.4.04 and 2.4.05.)

2.6.07. *Air.* The pump and suction-pipe must be tight, so that no air will leak in from the outside. There is always some air in the water, a part of which will be liberated in the pump on the suction-stroke, and probably only be slightly reabsorbed by the water on the working-stroke. Where the pumps are set at some distance below the station-tank, so that the water will flow into them, less air will be liberated. Some air in the water, if in small bubbles, is not objectionable, as it reduces shocks by acting as a cushion.

2.6.08. *Putting Pumps Out of Operation.* If water discontinues to come in at the lower levels of a mine, the pumps at such points must be put out of operation. This can be done by disconnecting the plungers or lift pumps; but then the work of the engine will generally be out of balance, because there is less resistance to be overcome on one stroke. If a lift pump be disconnected, the work on the up-stroke is decreased; if a plunger, then the work on the down-stroke is decreased. Lift pumps are easily disconnected. With plungers it is generally better to leave them connected, and to put them out of operation by propping-up the discharge-valve, so that it cannot close. A special arrangement is required for this, consisting of a lever on a shaft passing out through a stuffing-box in the side of the clack-chamber, and having a handle on the outside. In this way the pump-work will also be out of balance if the column-pipe is full, but for the stroke opposite to that for which it is out of balance when the pump is disconnected. By keeping the column-pipe filled to half its height, the work of both strokes will be equally reduced.

2.6.09. *Repairs; Stoppages.* Whenever it becomes necessary to stop for some time in order to make repairs, the bailing-tanks must be put in operation. For short stoppages and moderate inflow of water, it may be necessary to only speed up and pump down the tanks previous to stopping, so that the water from the upper levels will not come down and the sump water-level rise too much.

2.6.10. If the discharge-valve of a plunger pump requires repairs or changing, and there is no stop-valve above it, the water must be run out of the column-pipe; then the pump-work will be out of balance on starting up until the column is filled again, unless a supply for refilling is available on the surface. For this purpose a connection can be made to the column-pipe from the station-tank into which it discharges. A water supply at the surface can be used to make up the amount by overflowing successively from the different higher tanks until the one drained is filled. If the suction-valve of a plunger pump is to be inspected, the water must be let out of the space above it, and the inlet to the suction-pipe in the station-tank be closed by a water-tight cover.

2.6.11. A leaky valve can be detected by the diminished delivery of the pump. If the suction-valve of a plunger pump leaks badly, there is water-ram at higher speeds, because the pump does not fill and the plunger strikes the water with considerable velocity.

2.6.12. For warm water, and where the speed is great, and also in high altitudes, the station-tanks should be placed higher in relation to

the plungers than where the water is cold and the speed low, or where the height above sea-level is not great.

2.6.13. The velocity of water in column-pipes at mid-stroke should not exceed 5′ per second. (See 1.2.38.) If large column-pipes are used, the pumps may run somewhat faster on that account.

2.6.14. Cornish pumps are frequently run at speeds which, under ordinary circumstances, are not allowable, but which may be justified in controlling, temporarily, a sudden large influx of water. At the Ontario Mine, Park City, Utah, the rotative engine operated two 16″ plunger-sets of 10′ stroke, having a combined total lift of 455′, at thirteen strokes per minute. The engine is situated 7,500′ above sea-level, and the pump-chambers would not fill quickly enough, so that the resulting water-hammer frequently broke the column-pipes, which consisted of 15″ diameter hydraulic-tubing. The velocity of flow in the column-pipe was, at mid-stroke, nearly 7′ per second. Later, the same engine operated by means of a 16″ wooden rod 1,060′ long, two sets of 20″ plunger pumps of 10′ stroke, each set having a lift of 200′, the total lift being 400′ to the level of the drain-tunnel. Under these conditions the maximum speed of the pumps was eight strokes per minute, while the smoothest running was obtained at about six strokes. At the Combination shaft on the Comstock, before the hydraulic pumps were put in, there was a Davie non-rotative engine, operating a double line of 14″ plunger pumps by means of a pumprod over 3,000′ long; the maximum speed was about six strokes per minute, at which frequent breakdowns occurred.

SECTION III.

DIRECT-DRIVEN RECIPROCATING PUMPS.

CHAPTER I.

General Features.

3.1.01. The desirability, particularly in deep mines, of means other than the cumbersome pumprods for transmitting power to underground pumps, is continually leading to improvement in methods of transmission by steam, air, water, or electricity. The perfection of these has already done much to narrow the field of the old rod-pumping system. The greater simplicity and the cheapness of most of the direct-driven pumps have been sufficient incentives for their introduction in many places, the lower economy with which they operate being in many cases compensated for by the smaller capital invested in the plant. At present, however, considerable attention is being paid to improvement in economy, particularly of steam and compressed-air transmission, and it is to be expected that the direct-driven pumps will still further encroach upon the domain of the Cornish pump.

3.1.02. By direct-driven reciprocating pumps are meant those in which the pump-piston or plunger is rigidly coupled to, and moves coincidently with, the piston or plunger of a motor cylinder connected with the frame of the pump; the motive power may be steam, compressed air, or water. The pumps are always double-acting, and often duplex, like the Worthington, in which the two engines mutually control each other's valve-gear. They may be non-rotative or rotative, with or without a flywheel. Except in the case of sinking-pumps, they are nearly always horizontal.

3.1.03. Being double-acting, and having a comparatively short stroke, with very much smaller masses in motion than in the rod system, the direct-driven pumps are, unless the speed is limited by that of a hydraulic-pressure engine, capable of making a much greater number of strokes. They are, therefore, in the best position to utilize the advantages to be derived from the application of the air-chamber, with which they are commonly fitted on the discharge, or pressure, side, and often also on the suction-pipe. If the pump-stroke is long the admissible piston-speed will again be greater, because the number of reversals of motion is less.

3.1.04. On account of the double action in connection with the effect of the air-chambers, which tends to equalize the flow in the discharge-pipe, the water in the latter is kept continuously in motion in the same direction. The column-pipe can, therefore, be of much less diameter than with the single-acting Cornish pumps. As there is no stopping or back-flow of the water in the pipe, there will be fewer shocks, and higher speed of the pump will be admissible. Duplex pumps, which complete their strokes in regular rotation, maintain an almost uniform flow in

ıe column-pipe. The higher speed and consequently smaller size are ›atures which commend direct-driven pumps for use in mines. In the ıction-pipe, similarly, if an air-chamber is used, the column will be ıore uniformly kept in motion, and will, therefore, not lag back so

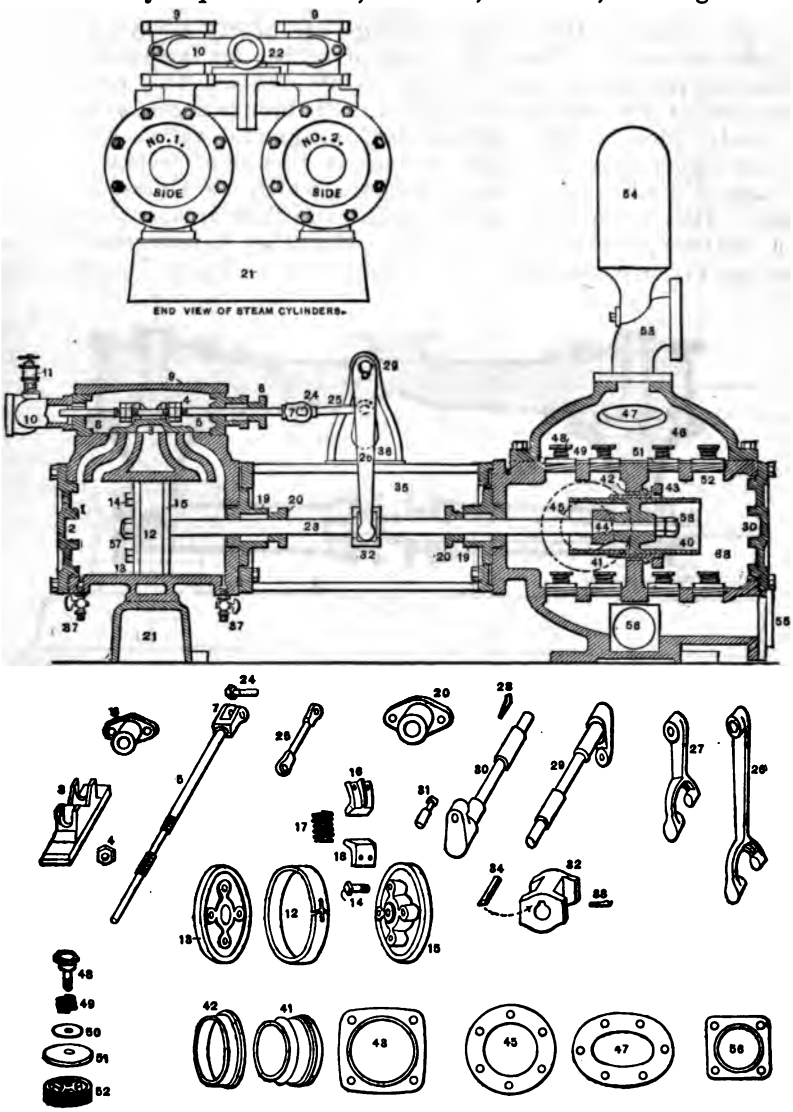

FIG. 117.

eadily for higher suction-lifts or greater speeds, and thereby fail to fill he pump-barrel. Higher suction-lift or longer or smaller suction-pipe ıay therefore be used.

3.1.05. Some pumps have such large waste-spaces that when the ıction-lift is great they will not prime themselves. In such cases a ›ot-valve should be placed at the lower end of the suction-pipe, and a

pipe connection made for filling the suction and also the pump from the column-pipe or other water supply. Expelling the air by admitting steam, which then condenses, will also prime the pump; this can be conveniently done where the exhaust is condensed in the suction-pipe.

3.1.06. *Valves.* Direct-driven pumps are nearly always fitted with straight-lift valves. These are made of rubber for low pressures, or of rubber-composition for pressures up to 200′. Above this pressure, and up to 400′ or 500′, rubber-composition with bronze cages, as in Fig. 36, are used. (See 1.3.09.) Beyond 500′ only metal valves will answer. For the larger sizes the valves are placed in sets of several; except in the case of mechanically operated valves, which are almost necessarily single. They are usually spring-loaded, and their area, or the aggregate area of those of one nest, is great, so that they have a small lift and close quickly on completion of the pump-stroke. Fig. 117 shows a pump

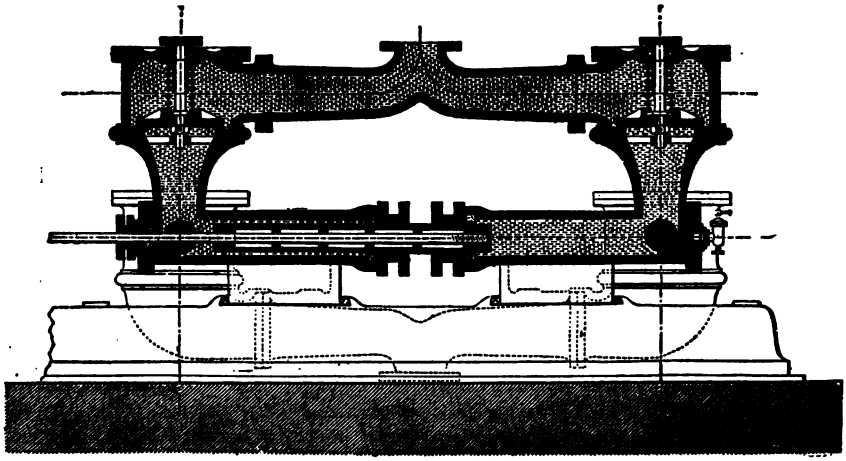

FIG. 118.

in section with multiple suction- and discharge-valves. Notwithstanding the large valve-area in the commonly used forms of pumps, the suction and discharge currents induced by the piston or plunger generally act locally with the greatest force on some only of the valves of a nest, causing these in particular to lift higher and to close more tardily than they should, while others remain almost closed, so that shocks are not avoided to the extent that might be expected by the use of a large number of valves alone. The reason of this is that the current is not diffused into a uniform stream of lower velocity corresponding to the valve-area, before it reaches the valves, but it rather breaks through portions of comparatively still or sluggish water. To overcome this defect Mr. G. Hanarte constructs pumps with valve-chambers designed so that the current is gradually and continuously increased in velocity from that with which it passes the suction-valves to that of the plunger, by the conoidal form of the elbow-chamber above the valves, and again reduced in velocity in a similar manner by the conoidal form of the chamber below the discharge-valves, as shown in Fig. 118. From the discharge-valves the velocity is again gradually increased by the conoidal entrance piece to the discharge-pipe. Such a pump, with piston

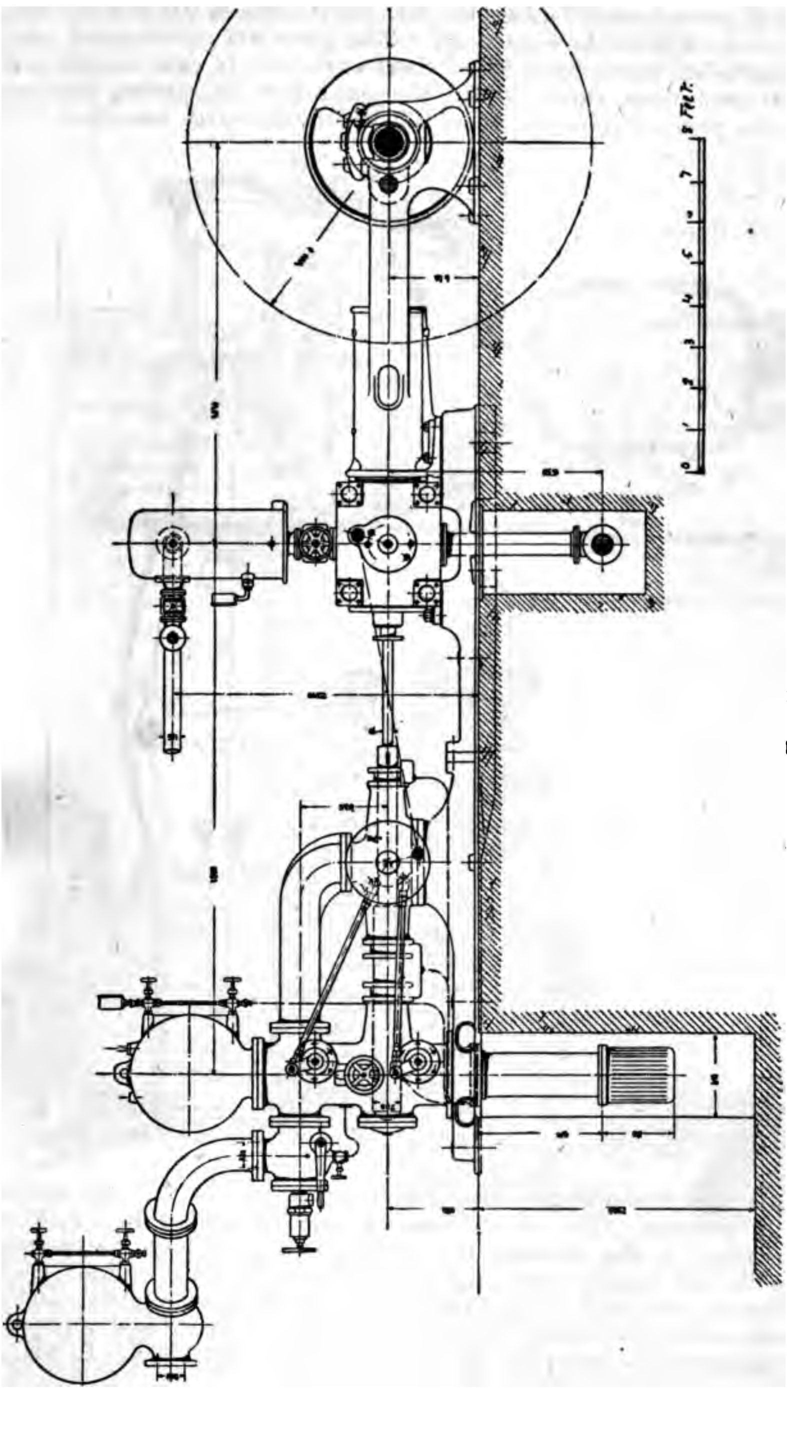

Fig. 119.

3″ in diameter and 12″ stroke, Mr. Hanarte has run at 400 double strok
per minute without the least shock. This gives 800′ piston-speed, whic
is remarkable, particularly for so short a stroke. In experiments mad
at 200 revolutions, and at 10′ lift, the pump gave 10% greater discharg
than the piston-displacement; at 100′ lift the discharge was equal to th

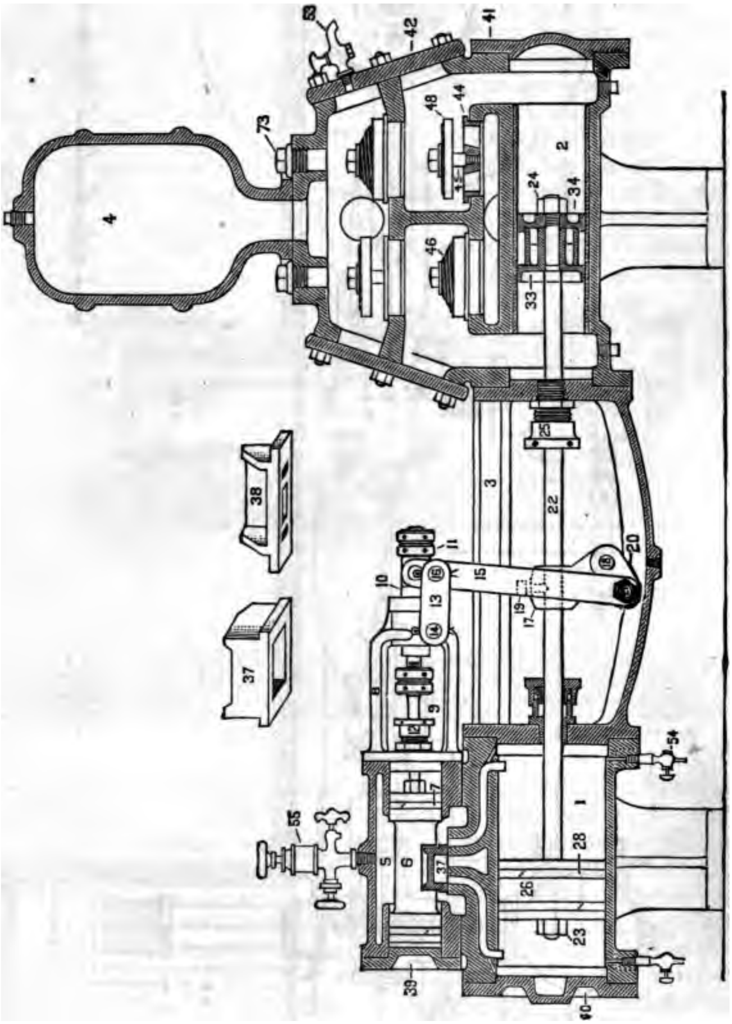

Fig. 120.

displacement, and at 200′ lift it amounted to 92% of it. The mecha
ically actuated valves of Professor Riedler, described in 1.3.18, an
illustrated in Fig. 42, have not admitted of such high pump-speed
The Riedler pumps have, on the other hand, been successfully used t
overcome very high lifts, a pump of 6″ diameter of plunger and 2C
stroke having been run at 80 revolutions per minute without appreciab
water-ram while pumping against a head of about 1,300′. In Fig. 11
is shown a complete Riedler pump.

3.1.07. *Piston Pumps.* Figs. 120 and 121 show common forms of these pumps. They are applicable for only moderate lifts, and where durability is desired they should be used only for pumping clean water.

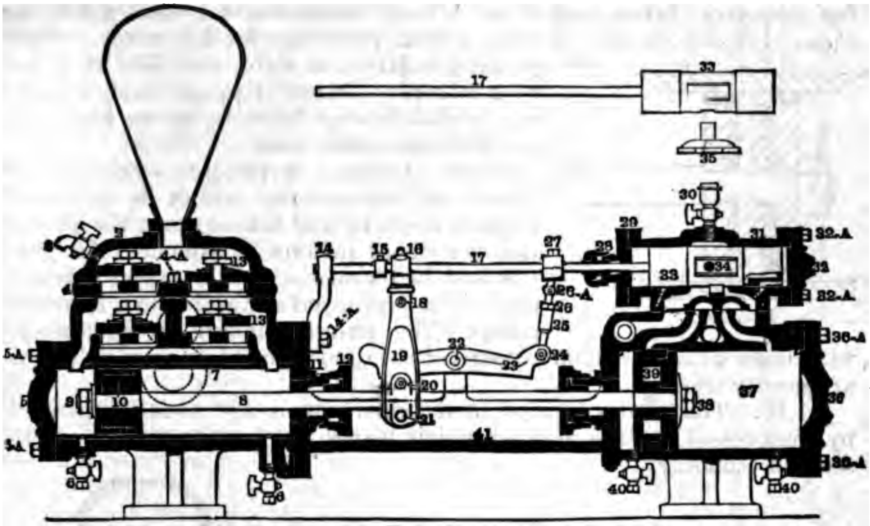

FIG. 121.

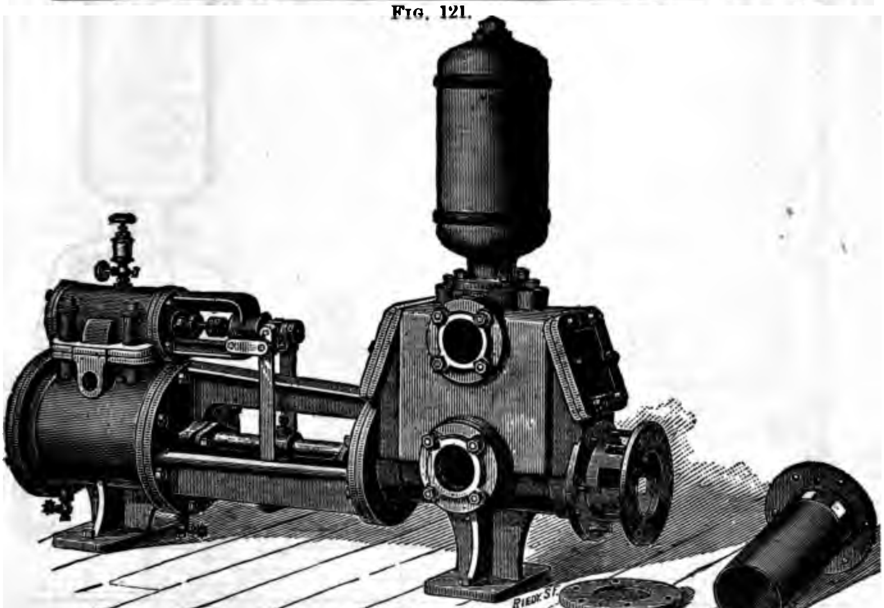

FIG. 122.

Common use is, however, made of the non-rotative form for feeder pumps to the station-tanks in mines; and in such duty they have to pump very dirty water, and also receive hard treatment otherwise. They are used for this purpose on account of their small weight, compactness, and low cost, and are run until they give out, when they are sent to the surface for repairs and replaced by others. Some of these pumps, like the one shown in Fig. 122, are made with exchangeable cylinder-liners,

so that the whole pump-cylinder will not have to be thrown away when its surface is worn out.

3.1.08. The piston-packing is usually similar to that used for packing plungers: hemp soaked in Albany compound for cold water, or square-braided cotton intermixed with plumbago for hot water. Such packing is driven in tight, and held in place by a follower. Rings of square rubber packing or double cup leathers, as in Fig. 123, are also sometimes used.

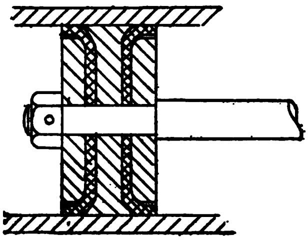

Fig. 123.

3.1.09. Leakage of pistons is not easy to detect, and the packing cannot be tightened without stopping and taking apart the pump. Lubrication of pistons is difficult. In Fig. 124 is shown a means of lubrication through the hollow piston-rod as applied to a Knowles pump. The pump-cylinders are best made with brass linings, but, on account of cheapness, the plain iron cylinders are mostly used.

3.1.10. The piston pumps used underground are usually operated by compressed air in a manner which leaves much to be desired on the score of economy.

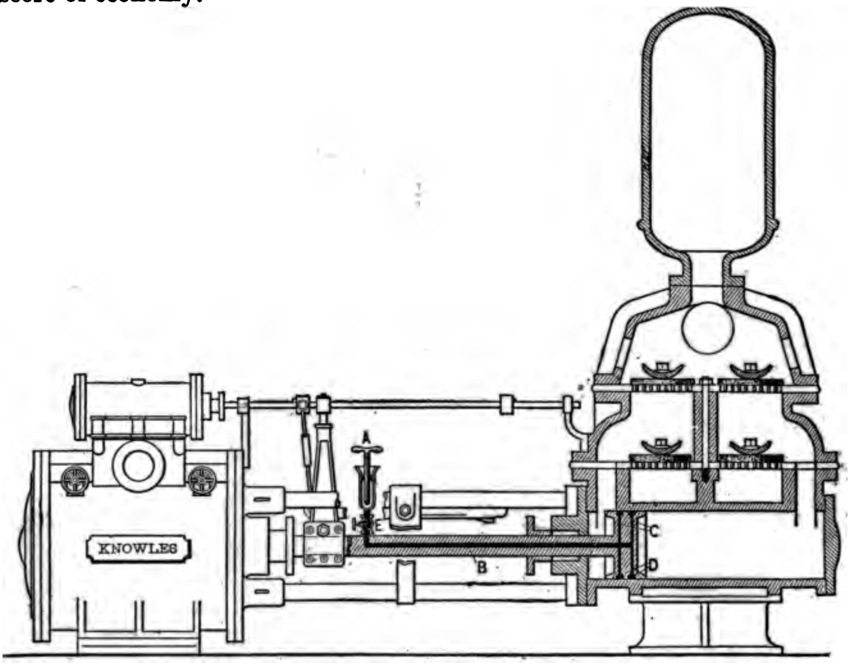

Fig. 124.

3.1.11. *Plunger Pumps.* Plungers have, in direct-driven pumps, the same advantages as in Cornish pumps, *i. e.*, the packing can be tightened while the pump is running, and they can be used for acid water and also for water carrying sand, though when horizontal, not with the same freedom from wear as vertical plungers. In direct-driven pumps they can be used for pumping against very high heads. The packing is the

same kind as used with the Cornish plungers. Figs. 125, 126, 127, 128, and 129 show common forms of high-pressure, double-acting plunger pumps. Brass plungers are often used, on account of the reduced friction and better resistance to acid water. In regard to plunger packing and lubrication, the same applies as remarked in 2.4.04 and 2.4.05.

3.1.12. In order to make the pump double-acting, either two plungers are connected oppositely, as in Fig. 125, or a double-ended plunger works in two oppositely located pump-barrels, as in Fig. 126.

3.1.13. A very compact form of pump results from the use of a so-called differential plunger. Such a pump is illustrated in Fig. 128. The area of the smaller part of the plunger, which, in reality, is only a large piston-rod, is half that of the large part. The pump has only one suction- and one discharge-valve, but is, nevertheless, double-acting, as far as resistance to motion is concerned, because only half of the water delivered through the discharge-valve is forced into the column-pipe, while the remaining half is drawn into the space surrounding the smaller part of the plunger, to be forced out again on the return-stroke, while the larger end of the plunger is drawing in water through the suction-valve.

3.1.14. A plunger without packing is shown in Fig. 117; the plunger slides simply with reasonable fit in a long sleeve, the

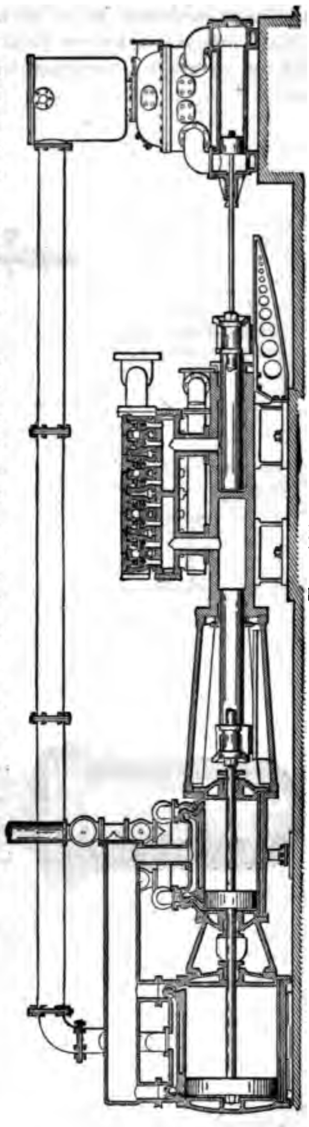

Fig. 125.

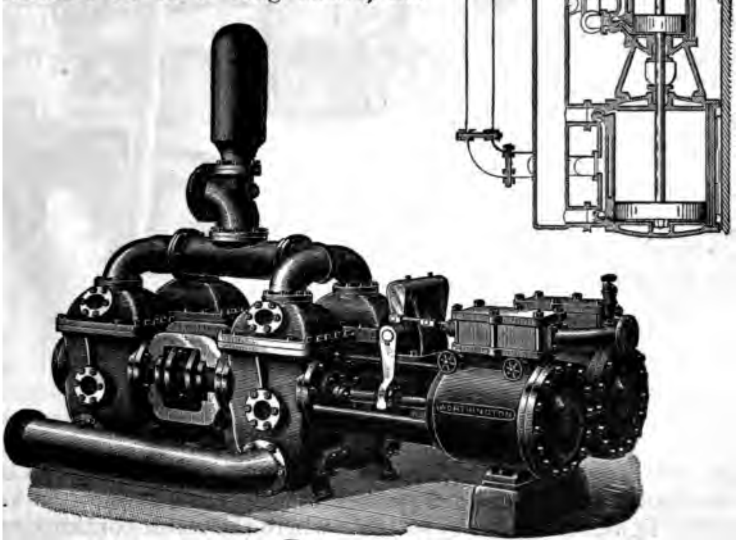

Fig. 126.

lubricant serving as a sort of packing. The plunger is made hollow, and of such thickness that it will be of the same weight as an equal volume of water, thereby causing it to exert no pressure on the sleeve,

FIG. 127.

thus reducing the wear. The sleeve should be made so as to be readily interchangeable. For high pressures this form cannot be kept sufficiently tight, and it is not suitable where the water contains much grit.

3.1.15. Another form is the bucket-plunger (Fig. 130), which is suitable only for vertical pumps, such as sinking-pumps, and for clean water. The water here passes through the plunger and the discharge-valves, which are located on top of it. The pump shown also utilizes the differential principle, described in 3.1.13.

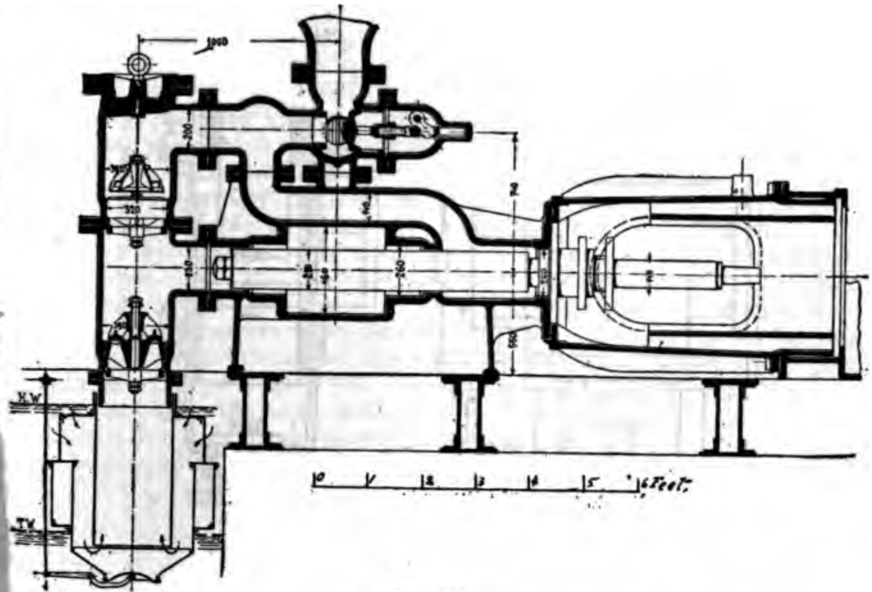

FIG. 128.

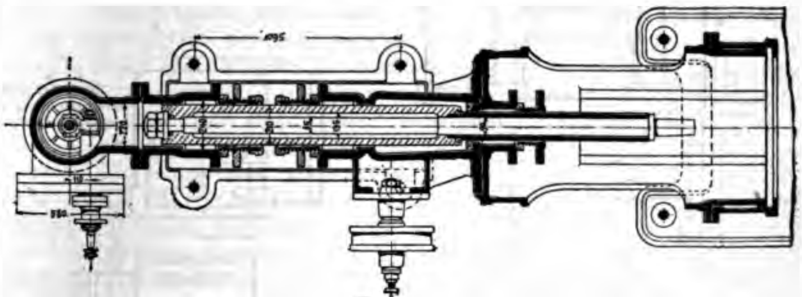

FIG. 129.

3.1.16. *Air-Chambers.* The object of air-chambers, as stated in 1.2.42 and 1.2.44, is, firstly, to change the intermittent motion of the water moving with the pump-piston or plunger, into a flow as uniform as possible in the discharge-pipe; and, secondly, to reduce the shocks or water-ram. Pumps fitted with properly proportioned air-chambers can be run at greater speed and against higher heads than those not so provided, because the mass of water reciprocated by the pump is comparatively small in the former. It follows, in order to keep this mass a minimum, that the distance between the discharge-valve and the air-chamber should be as short as possible; therefore, an air-chamber should, in large pumps, be placed directly over each set of discharge-

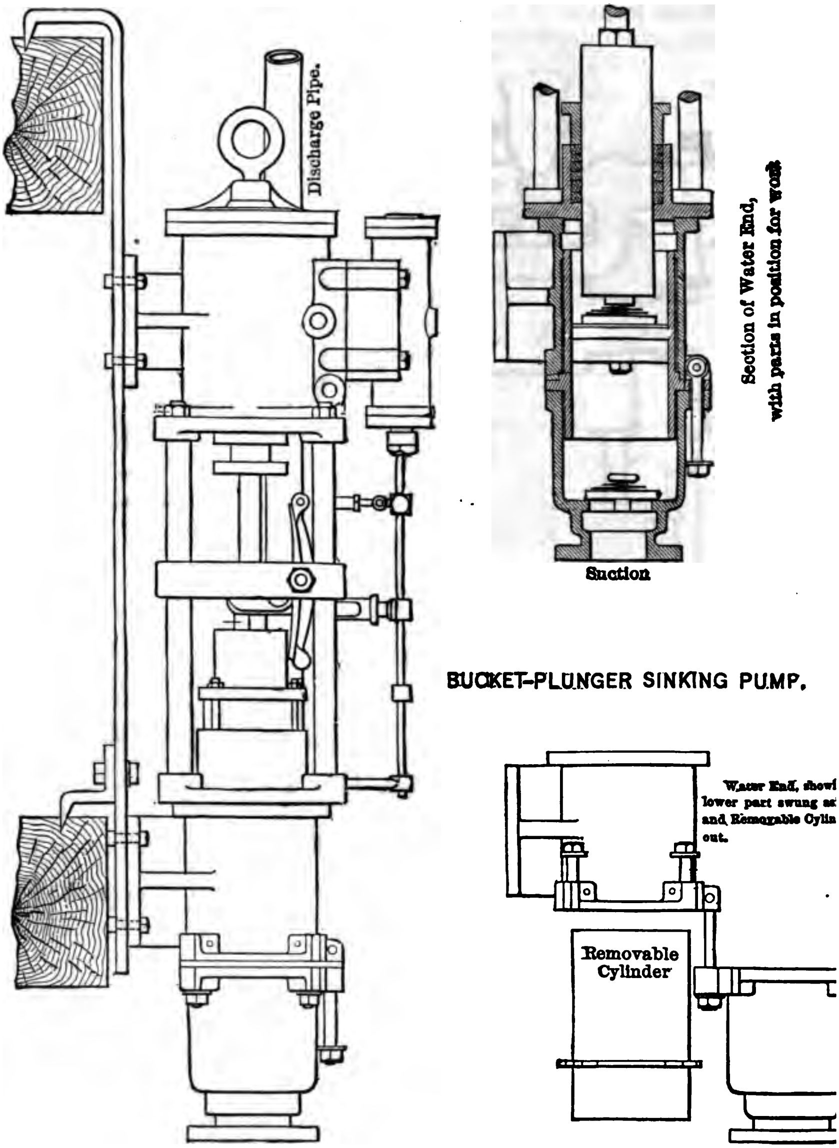
Discharge Pipe.
Section of Water End,
with parts in position for work
Suction
BUCKET-PLUNGER SINKING PUMP.
Water End, showi
lower part swung as
and Removable Cylin
out.
Removable
Cylinder

FIG. 130.

valves. Rarified-air-chambers are often used below the suction-valves to equalize the flow in the suction-pipe.

3.1.17. The requisite volume of air-chamber is largest for single-acting pumps, much less for double-acting ones, still less for duplex double-acting, and least for triple pumps.

3.1.18. In the pressure air-chambers the air is generally absorbed by the water; in the suction air-chamber it is liberated. Pressure air-chambers, therefore, generally require replenishing from time to time. This may be done periodically by a small hand air-pump, or automatically by one operated by the pump. The usual plan is to admit a small quantity of air at each suction-stroke into the space between the suction- and delivery-valve by means of a small pipe provided with a cock to regulate the quantity of air to be admitted, and also, so as to prevent outflow on the working-stroke, with a check-valve.

3.1.19. Air-chambers, particularly those of cast-iron, should be tested for tightness under full pressure, and then painted on the inside. For light pressures gauge-glasses will answer to indicate the water-level, but for higher pressures try-cocks must be used. It is also advantageous to have a pressure-gauge on the air-chambers, which will indicate the fluctuations of pressure. Of course, the use of such appliances is warranted only with larger pumps.

3.1.20. Instead of air-chambers, spring-loaded plungers or pistons have been applied in some recent high-lift pumps. (See 1.2.44.)

CHAPTER II.

Non-Rotative Pumps.

3.2.01. Non-rotative pumps, commonly termed "direct-acting pumps," are the type of the direct-driven pumps most generally used in this country. They are cheaper, occupy less space, are more easily erected, and can be run at much slower speeds than single steam or compressed-air pumps fitted with cranks and flywheels. They are designed for operation by steam, by compressed air, and, in some cases, by hydraulic pressure. They are less economical in operation by steam or compressed air than the rotative type, because they cannot utilize the benefit of expansive working to any extent and have to work with considerable clearance in the steam cylinder, being, in this respect, in a position similar to that of the rod-pumping steam engines of the Cornish, Ehrhardt, or Davie types, described in 2.5.05 to 2.5.08. As in these, compounding improves their economy. For larger units the station pumps are generally constructed on the duplex plan, as illustrated in Fig. 126, first introduced by Henry Worthington. Duplex pumps admit of higher piston speeds than single pumps, because with them the column of water is kept in more uniform motion; they are also more easily started.

3.2.02. The station pumps are always horizontal, while the sinking-pumps are generally vertical or inclined in the line of the shaft.

3.2.03. The direct-acting pumps built by the various manufacturers differ chiefly in their mechanism for effecting the distribution of steam. Those illustrated and previously referred to show some of the great variety in existence.

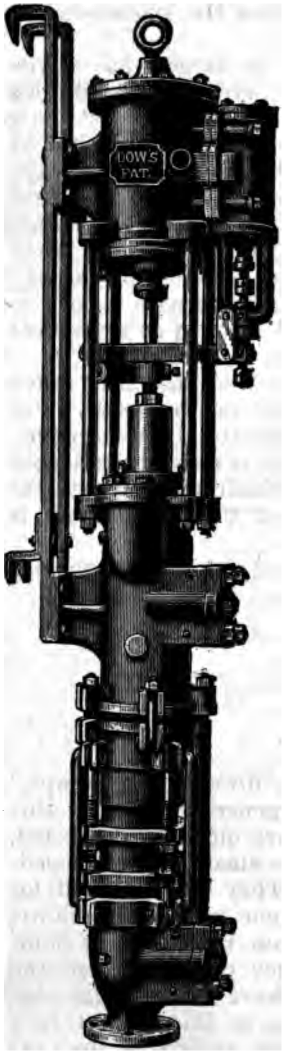

FIG. 131.

3.2.04. *Sinking-Pumps.* For direct-dr sinking-pumps the non-rotative type is the suitable one. Figs. 130 and 131 show typ these. Those to be operated by steam usu have a condenser for the exhaust steam loc in the suction-pipe, as in Fig. 132, which i trates in section a large pump of a style n used on this coast. Duplex sinking-pump which the Worthington is a type, are not so extensively, on account of the amoun space they occupy in the shaft.

3.2.05. The suction-pipes are always of l and often have a foot-valve just above strainer, in order to keep the suction fu water whenever the pump is stopped for lo ing or raising or for repairs to the suc valves. This foot-valve should properly re open during the operation of the pump, and close with the suction-valves, so that the suc resistance may not thereby be unnecessaril creased. There should be a relief-valve in part of the suction-pipe, whenever a foot-v is used at the lower end of the hose, so that any leakage past the suction-valve, while the pump is stopped, will not burst the hose, but will be permitted to escape under a moderate pressure. The suction-hose should be wrapped with rope to protect it during blasting.

3.2.06. Sinking - pumps are generally obliged to handle water full of grit, it being impracticable to settle it in a large reservoir, as is done with the station pumps. The larger the cross-section of suction-pipe and the less, therefore, the velocity of the water in it, the less also will be the amount of sand drawn up into the pump. But this expedient is generally not sufficient to protect the pump and to prevent the necessity of its early removal for repairs. This difficulty, in one case of a large pump, led to the design of a settling-chamber attached below the pump, as shown in Fig. 133. The two suction-branches *a a* entering the chamber are bent over so as to discharge circumferentially and cause the water to assume a rotary motion, whereby the sand is driven by centrifugal action against the wall of the chamber and falls to the

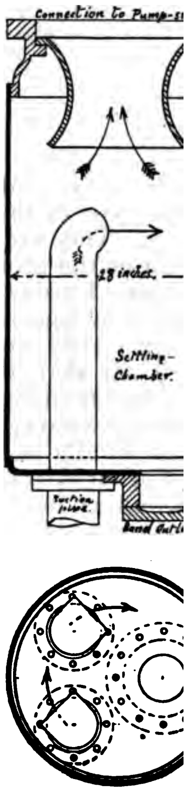

FIG. 133.

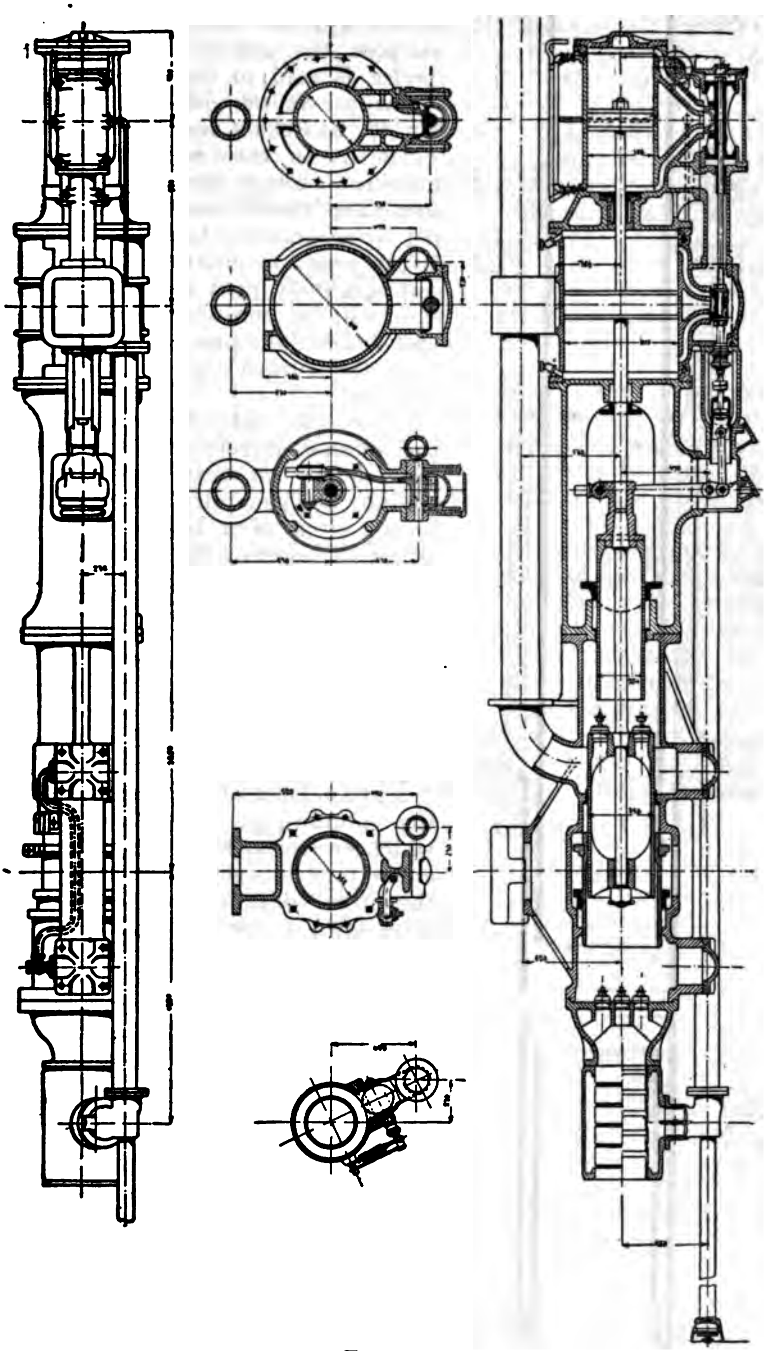

FIG. 132.

bottom, whence it is periodically withdrawn through the outlet *b*, for which purpose the pump is stopped. This device is said to have operated satisfactorily. It was jointly designed by Mr. W. R. Eckart and Mr. G. Dow.

3.2.07. In case of a sudden, large inrush of water the sinking-pump is sometimes raised and the water permitted to accumulate to a depth of about 10′, in order to obtain a large body of comparatively quiet water, in which the sand will be more liable to come to rest and settle. The pump then draws from near the surface where the water is cleanest.

3.2.08. In order to be able to lower the pumps conveniently and with the least delay, the steam-pipe and water-column are generally made with slip-joints, often of a length sufficient to admit of lowering the pump for a distance equal to the length of a full section of steam- or column-pipe. When shorter slip-joints are used, a short section of pipe must be kept ready to be put in and taken out alternately between permanent insertions of full sections. Fig. 134 shows the construction of a long slip-joint or telescope.

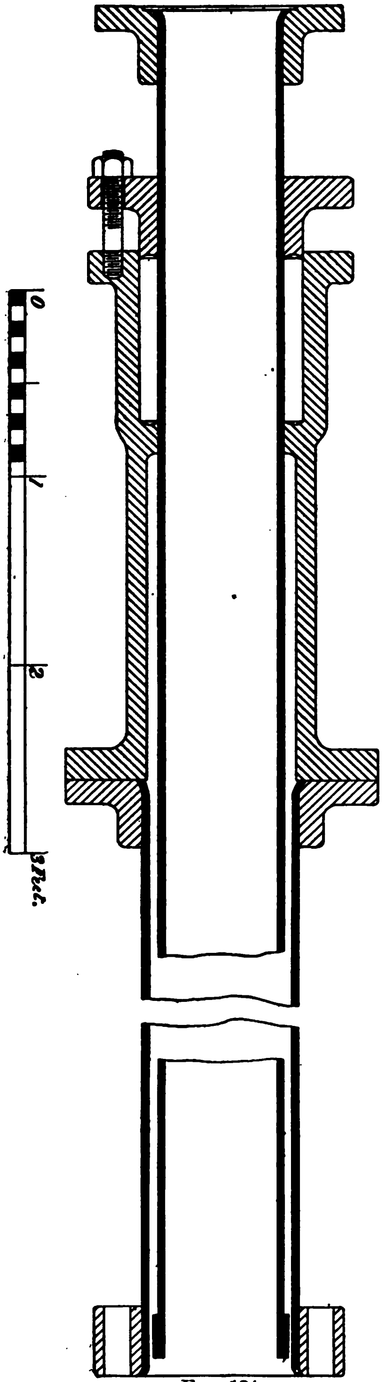

Fig. 134.

3.2.09. Instead of inserting pieces in the column-pipe above the slip-joint, which necessitates the emptying of the entire pipe, it is generally better to lower the entire column when the pump has gone down as far as the slip-joint will permit, and then to add the necessary length to the upper end. Sometimes, also, the column is lowered with the pump, and then no slip-joint or telescope is required. For the steam-pipe the telescope is always required. There should be a gate-valve at the discharge connection of the pump, so that, when internal repairs or adjustment of the pump becomes necessary, the water will not have to be drained out of the column. This applies also to station pumps. (See also 1.3.28.)

3.2.10. The pump is generally raised and lowered by means of a chain-block suspended from a beam thrown across the shaft timbers. Where it is desirable

to lower the pump for some distance, say equal to the length of a pipe-section, the chain should be lengthened, as the blocks usually admit only of a lift of about 10′. Large pumps are often handled by hoists from the surface.

3.2.11. The smaller pumps are usually secured by heavy iron claws attached to the pump, which hook into the top of the shaft sets. Large pumps are best provided with regular guides, to keep them in line with the steam- and column-pipes. Incline pumps of large size are usually mounted on flanged wheels guided on a track of wood or on iron rails.

CHAPTER III.

Rotative Pumps.

3.3.01. In these the motor- and pump-cylinders are also connected, so as to move coincidently, like in the non-rotative pumps, but they are further arranged with a crank coupled by a connecting-rod to a cross-head moving with the pistons or plungers. They can be operated by steam or compressed air; for operation by water pressure the rotative engines are not well adapted.

3.3.02. Single pumps require a flywheel, but the duplex pumps can often dispense with one. On account of the crank and flywheel, rotative pumps can complete their stroke close up to the steam-cylinder-heads, and therefore have little clearance as compared with the non-rotative pumps. For this reason, and also because they can utilize the expansion work of steam or of reheated compressed-air, they operate more economically than non-rotative pumps. By varying the point of cut-off of the steam or air, the work per stroke can, as in the rotative rod-pumping engines, be varied within much wider limits than in the non-rotative pumps. This is useful in adapting the pumps to increase of lift.

3.3.03. Single rotative pumps cannot be run below a certain speed. Duplex rotative pumps can be made to run very slowly, and are therefore capable of a wide range of capacity.

3.3.04. Rotative pumps are the only ones which admit of the use of mechanically actuated pump-valves. The well-known Riedler pumps, referred to in 1.3.18, are rotative.

3.3.05. The rotative principle, as stated in 3.2.04, cannot well be applied to sinking-pumps, as the space occupied would be too great, and the rough treatment to which such pumps are subject would soon unfit them for service.

3.3.06. Rotative station pumps require much better and more extensive foundations than the non-rotative pumps. The stations must also be larger. On the other hand, the rotative flywheel pump generally admits of higher speed than the non-rotative, and can therefore be made of smaller size. Examples of speeds and lifts attained in practice with the best modern types, like the Riedler and Hanarte pumps, have been given in the preceding pages.

CHAPTER IV.

Underground Pumps Driven by Steam.

3.4.01. *Steam Supply.* It is not often possible to place steam boilers under ground, as they require large excavations, around which the ground must be well supported; the smoke and waste gases must be led to the surface; the fuel must be brought down, and the ashes raised or transported; generally, also, the mine-water is unfit for boiler use, and suitable water has to be led down from the surface. For these reasons underground steam pumps are nearly always supplied with steam by means of pipes leading from boilers located at the surface. Such pipes have been described in Section I, Chapter II. It was there stated that they should be well protected by non-conducting covering to prevent excessive loss of heat; that it was an advantage to have a reservoir or drain interposed between the pump engine and the steam-pipe, in order to produce a more uniform flow in the steam-pipe and to keep up the initial pressure in the steam-cylinder; and that there should always be a valve in the pipe at the surface, besides one at each pump.

3.4.02. *Types of Steam Pumps.* In the United States underground pumps are mostly of the direct-acting type, although recently rotative Riedler pumps have come into use in a few places. The reason for the preference of the non-rotative pumps has been stated in 3.1.01 to be due to their greater compactness, simplicity, cheapness in the case of smaller sizes, and minimum of attendance required; also, because economy in the use of fuel, particularly in smaller plants, is generally of less importance than other considerations. The necessarily non-rotative sinking-pumps are not economical in the use of steam, even when arranged on the compound principle, because they have to meet great variations of pressure, and, as they are proportioned to work with full pressure at their limiting lift, the steam has to be very much throttled while they are operated under lower lifts. Direct-acting station pumps can be better proportioned to their work than sinking-pumps, and can utilize the advantages of compounding. They can also be fitted with steam-jackets and independent exhaust-valves, which materially adds to the economy in use of steam or air.

3.4.03. The Cross compound rotative engines, driving Riedler pumps at the mines of the Boston and Montana Gold and Silver Mining Company, are compound Corliss condensing engines. Being arranged on the duplex plan, they can run at a high speed; and as the cranks are at right angles to each other, the speed can also be reduced to a very low limit.

3.4.04. Pumping engines should be fitted with a governing device to keep the speed below the permissible maximum, which might otherwise be exceeded in case of breakage of the column-pipe near the pump, whereby the resistance would be thrown off the pump and engine. There should also be a control of the steam admission by a float in the station-tank, so that the speed of the pump will adapt itself to the flow of water coming into the tank. These remarks apply also to pump engines operated by compressed air or water.

3.4.05. With compound engines the steam pressure should not be lower than 100 lbs., in order to secure sufficient benefit from its expan-

sion. With single-cylinder engines the pressure is usually 70 to 80 lbs. With triple-expansion engines the steam pressure should be still higher than with the compound engine, in order to secure sufficient additional economy to warrant their extra cost.

3.4.06. Large compound engines should have their valve-gear so arranged that the points at which cut-off occurs in the high- and low-pressure cylinders can be adjusted in relation to each other. It is also proper to have the amount of compression adjustable. With smaller pumps, such refinement would be too expensive, and the mechanism also liable to get out of order through lack of attention. Large engines are usually under careful supervision, and there steam-saving appliances will pay.

3.4.07. *Condensation of Exhaust-Steam.* Steam pumps, when used at moderate depth, can have their exhaust-steam conducted to the sur-

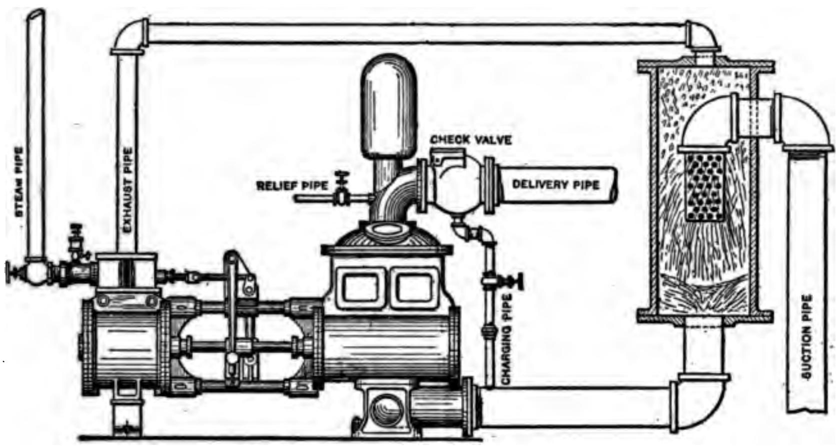

FIG. 135.

face. Condensation of the steam exhausted from deeply located underground pump engines is always necessary in order to get rid of the vapor and heat by conveying these to the surface in the water pumped. Sometimes such condensation is carried on at atmospheric pressure, in which case no economy to the engine results. It may be necessary to do this where the mine-water is very warm, and advisable in very high altitudes where the barometric pressure is so low as to afford little advantage in extra effective steam pressure. Generally, however, the steam is condensed under a very low pressure in the ordinary manner.

3.4.08. Condensation of the steam may be carried on either in the suction-pipe, which is the universal practice with sinking-pumps, or by means of an independent condenser with air-pump, like in the case of most of the large station pumping-plants.

3.4.09. Where condensation is effected in the suction-pipe, the steam should enter the latter in a direction almost parallel to the flow of water, so that it will act like an injector and thus aid in accelerating and lifting the water. Such a condenser is attached to the sinking-pump in Fig. 132.

3.4.10. The amount of vacuum obtainable by this method of con-

densation depends upon the suction-lift; the greater the latter, the l
is the vacuum obtained.

3.4.11. With horizontal pumps, such as are used at the station
suction-lift is usuall
and there is dang
the water rising int
steam-cylinder, pa
larly when the pu
stopped. A small
at the upper part c
pipe, opened as so
the pump is sto
would prevent thi
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Such cocks are, how
liable to be forgotter
in some places it has
found safer to dr
small hole into the
which will contin
admit some air, a
sacrifice of a part c
vacuum. A better
is to carry up th
haust-pipe sufficie
high, and then drop
the condenser, as
trated in Fig. 135, s
the bend will be
the top of the colu
water due to baron
pressure. The lo
point of the exhaust
can readily be dr
by a small pipe ru
down in a corner c
shaft, with its lowe
dipping into a ves
water placed at su
depth below the exh
outlet on the cyl
that the outside ai
not force the wat
into the exhaust-
With vertical sin
pumps, where the st
cylinder is located
considerable height
the condenser, the
usually no danger of the water ever reaching so high, unless the p
is working close down to the water-level.

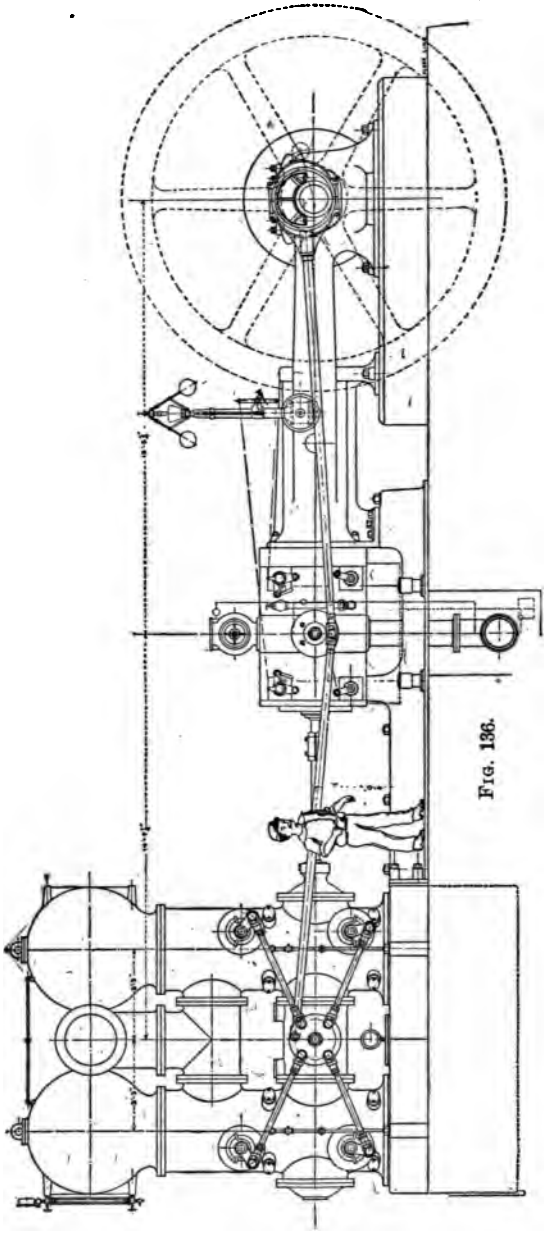


FIG. 136.

3.4.12. Station pumps are generally arranged with air-pumps

condensers independent of the suction-pipe. In this case also the injection-valve for the condensing water must be closed as soon as the engine is stopped, so that water may not rise into the steam-cylinder. This danger can be avoided by the submerged drain extending down the shaft, as described in the preceding paragraph. The air-pump is either driven from the pump engine, or operated by an independent engine; the former plan is the most common with rotative engines. Figs. 136 and 137 show a Riedler pump equipped in this manner. Direct-acting pumps are usually arranged with an independent air-pump, as in Fig. 138, and the latter often serves for a number of pumps.

3.4.13. Where there is a chance for leading the exhaust to the surface the exhaust-pipe leading to the condenser should have a branch-exhaust into the atmosphere, closed by a tight stop-valve when the condenser is running. A valve to close communication with the condenser, while the engine is exhausting into the atmosphere, should also be inserted, so that repairs can be made without stopping the pump.

3.4.14. *Mechanical Efficiency of Direct-Driven Steam Pumping-Plants.* While large, triple-expansion pumping-engines of the best design and most efficient type have,* when in best adjustment, reached, under test, a pumping effect of 1 H.P. per hour on less than 1½ lbs. of good coal, even the best class of underground steam-operated pumps will probably never be able to approach such a result. If an efficiency of 1 H.P. on 2½ lbs. can be attained, it may be called a very excellent result. The ordinary small, direct-acting, single-cylinder pumps, even in their best condition, probably consume about five or six times that amount of fuel, but when leaking and badly adjusted, as is so often the case, ten times may not be an excessive estimate.

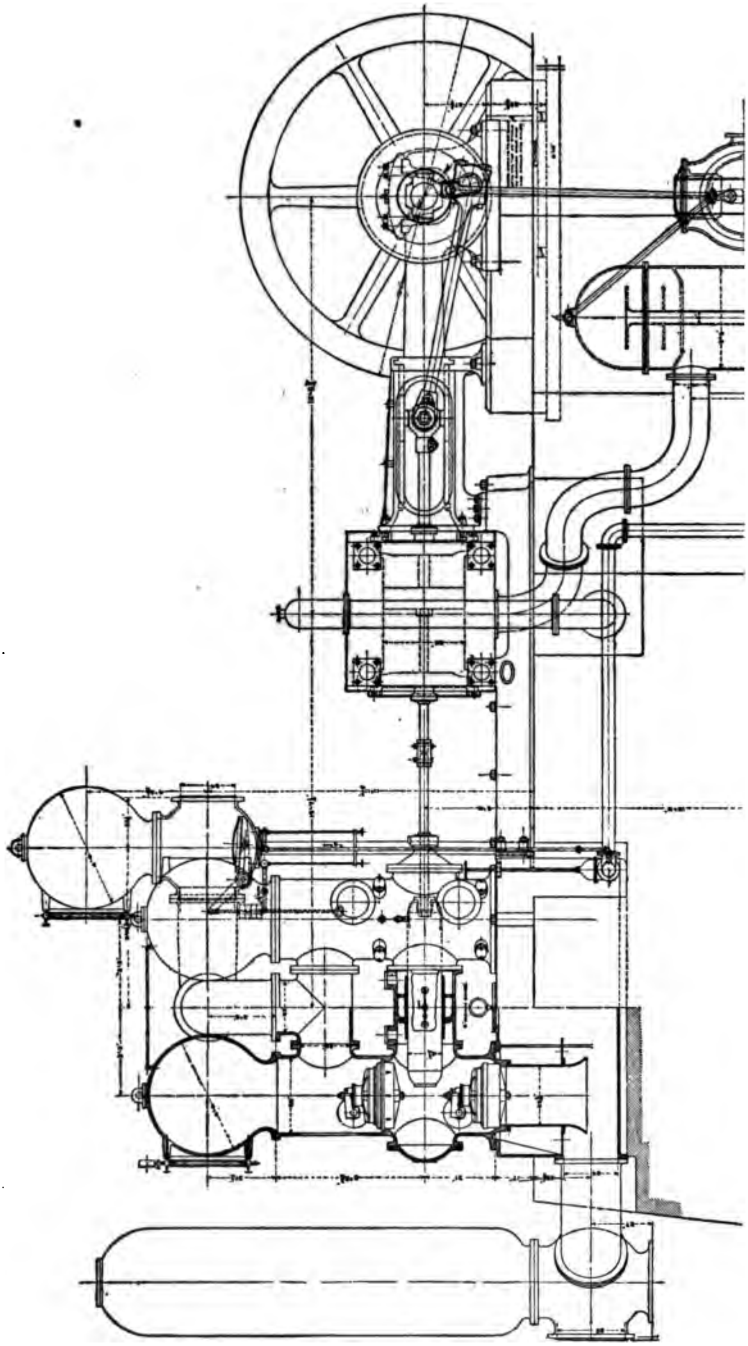
CHAPTER V.

Underground Pumps Driven by Compressed Air.

3.5.01. *General Remarks.* The transmission of power by compressed air is one of the most convenient, and, if properly carried out, a very economical method of operating pumps and other machinery underground. It has the advantage over direct steam that it requires no condensers; that its exhaust cools instead of heats the air in the shaft or stations, and can be turned to use in assisting ventilation; and finally, that it is generally essential for operating machine-drills and other machinery at points removed from the shaft, where the use of steam would not be admissible. There is, in addition, very little danger from the rupture of a compressed-air-pipe such as there is with steam-pipes.

3.5.02. *Efficiency of the Old System.* - In the majority of the smaller plants equipped with ordinary compressors and pumps driven by single-cylinder engines, which receive the air without previous reheating, the mechanical efficiency is very low. In the first place, there is a loss in the compression of air by part of the energy expended upon it being converted into heat, which is afterwards dissipated, thereby reducing the volume of the air before it reaches the engines which it is to operate.

*The case referred to is that of the Milwaukee pumping-engine built by the E. P. Allis Company. Of the coal used, 1 lb. evaporated over 9 lbs. of water.



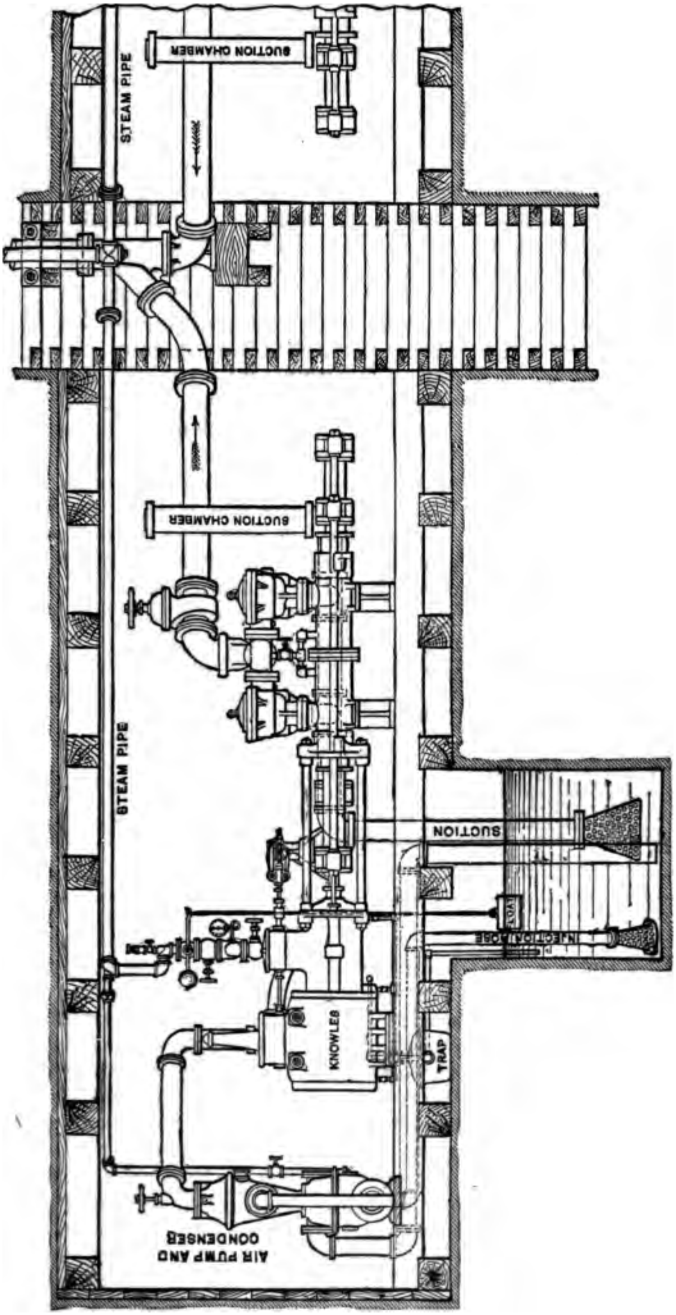

SUCTION CHAMBER
STEAM PIPE
SUCTION CHAMBER
STEAM PIPE
SUCTION
KNOWLES
TRAP
AIR PUMP AND CONDENSER

FIG. 138.

In the ordinary types of the latter also, if the air is admitted at the ordinary temperature, the work of expansion cannot be utilized, because the air on expanding is lowered in temperature to such an extent as to freeze the entrained moisture, which thereby blocks the engine in a very short time. The diagram, Fig. 139, illustrates the relation of the work expended in compression to that performed in the engine. It is laid out for a pressure of six atmospheres, or nearly 90 lbs. absolute or 75 lbs. gauge pressure, and a volumetric effect of the compressor of about 90%. The line AB is the compression line, such as is usually obtained in an ordinary single-cylinder compressor without spray-injection. The area ABDE, shaded in horizontal lines, then represents the work performed on the air in the compressor-cylinder. The distance BC represents the reduction in volume of air due to cooling to the temperature of the atmosphere before it reaches the motor engine. The distance DF represents the loss of pressure due to resistance of the pipe-line. The distance from the line IK to the atmospheric line 1 is the back pressure on the motor piston. Finally, the area FJGKI, shaded in vertical lines, represents the work capable of being expended on the piston of the motor in case a moderate expansion and compression into the clearance spaces is admissible, as in the case of rotative pump engines. The proportions of the areas ABDE and FJGKI give the relation of the indicated work expended upon and

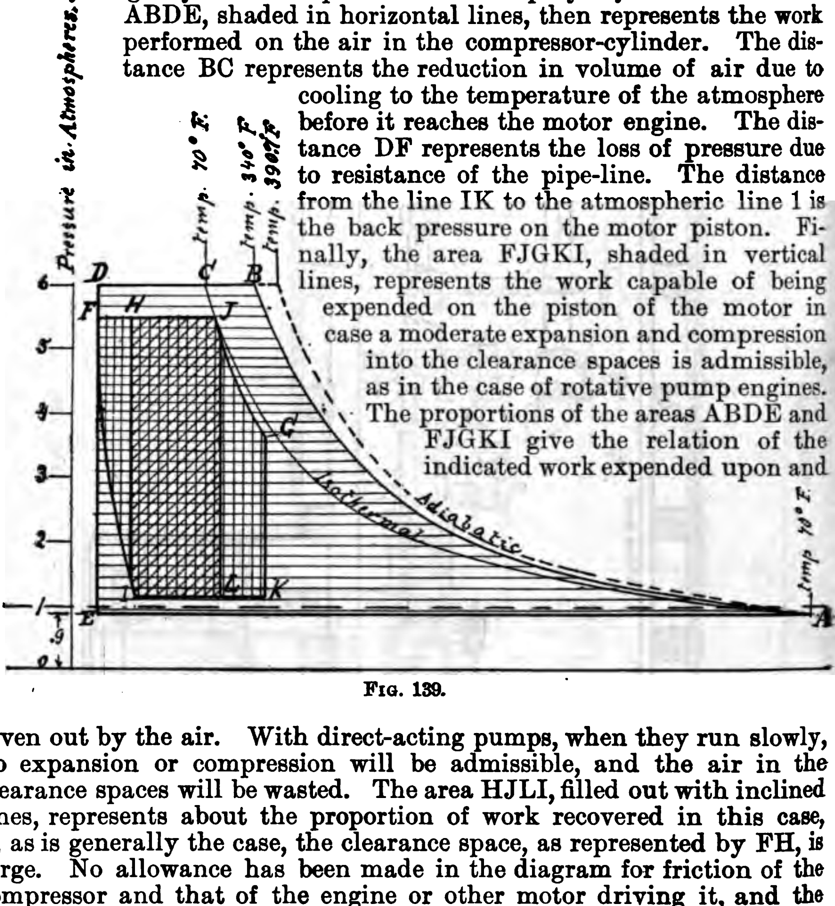


FIG. 139.

given out by the air. With direct-acting pumps, when they run slowly, no expansion or compression will be admissible, and the air in the clearance spaces will be wasted. The area HJLI, filled out with inclined lines, represents about the proportion of work recovered in this case, if, as is generally the case, the clearance space, as represented by FH, is large. No allowance has been made in the diagram for friction of the compressor and that of the engine or other motor driving it, and the friction of the pumping-engine and pump. These several losses will again increase the work of compressing the air and reduce that capable of being done by the pumping-engine; from all of which it is apparent how low is the efficiency of this method of using compressed air.

3.5.03. *Modern Efficient Compressed-Air Transmission.* Improvement in efficiency of compressed-air transmission must be effected, first, by reducing the work of compressing air; and, second, by utilizing the work stored in the compressed air to the best advantage.

5.04. The work of producing the compressed air can be improved, ly, by increasing the volumetric effect or fill of the compressor. ; can be effected by large, light valves, preferably operated by hanism. Secondly, by cooling the air more effectually during comsion, either continuously by surface cooling or spray-injection of er, or in stages between the partial compressions, in a series of two nore cylinders, so that the temperature is reduced as much as pos- e during compression or between stages of compression, with attend- reduction of the work necessary to bring the air to the required lition.

5.05. The work obtainable from the compressed air delivered to the driven engine may be increased by enabling the air to work expansively. If the air were perfectly dry, expansion could be utilized directly; but as this is never the case, the air must be reheated, the heat thus expended having the additional effect of increasing, in proportion to the heat added, the volume, and thereby the amount of work obtainable from the air. In compound pumping-engines, the air should be reheated in two stages, and to a more moderate degree. This would be an advantage in a mine, where the heat can generally be imparted more conveniently to the air by means of the limited tempera-

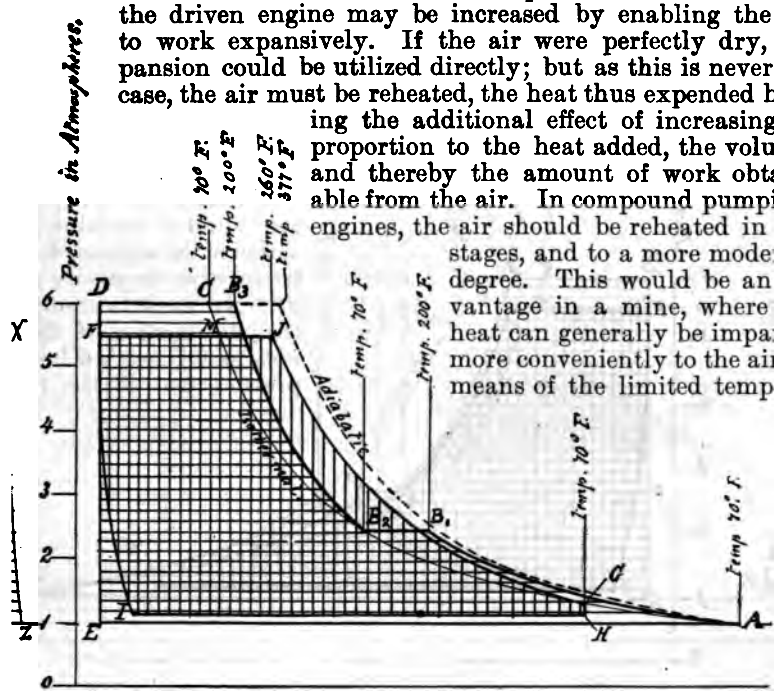


FIG. 140.

ı of steam conveyed to a heater located near the pump underground. air-pipes can be smaller than in the common system, because less ;ht of air is required in the pump engine to do a given amount of work.

5.06. The reheating of the air, by whatever means effected, is best ormed close to the pump engine. If the reheating be carried on at surface, the air-pipes have to be larger, in order to pass the increased ıme of the heated air. Such pipes also require good non-conducting ›ring.

5.07. In order to give the best effect, the reheating should be only sufficient that the air after expansion in the engine will have the perature of the surrounding air.

5.08. It is to be noted that the expansive work of the air, like that team, can only be well utilized in rotative engines, and only imper- .y in direct-acting ones at high speed. Compound, direct-acting

pump engines are better situated in this respect than the single-cylinder type, as they admit of a wider range of expansion for the same variation of pressure per stroke.

3.5.09. The diagram, Fig. 140, illustrates the result of increasing the volumetric effect and compounding the compressor, and of reheating the air to about 260° Fahr. before it enters the pump engine, thus increasing its volume from FM to FJ. The pressures are the same as for the diagram, Fig. 139. The horizontally shaded area $AB_1B_2B_3DE$ represents the work spent in compressing the air, while the area FJGIH is that capable of being done by the air when reheated to 260°. The area WXYZ represents the additional work that could be utilized in the compressor for an expenditure of fuel equal to that used in reheating the compressed air. This area must be added to the compressor-diagram $AB_1B_2B_3DE$ before comparing it with the diagram of work capable of being performed by the reheated air. A compound compressor can be run at higher speed, and consequently be of smaller size, than a single-cylinder machine, if the action of the admission-valves be such as to insure a good fill. In such a compressor the chief cooling of the air is not performed during compression, but in the receiver

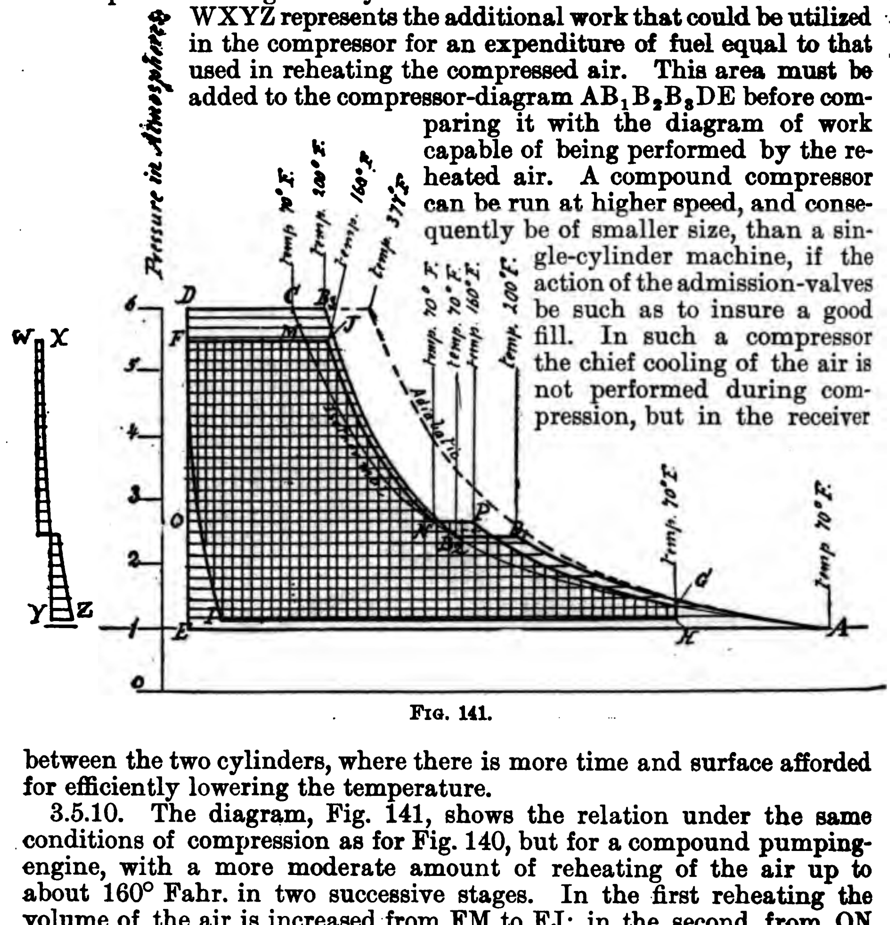


FIG. 141.

between the two cylinders, where there is more time and surface afforded for efficiently lowering the temperature.

3.5.10. The diagram, Fig. 141, shows the relation under the same conditions of compression as for Fig. 140, but for a compound pumping-engine, with a more moderate amount of reheating of the air up to about 160° Fahr. in two successive stages. In the first reheating the volume of the air is increased from FM to FJ; in the second, from ON to OP. The area WXYZ represents the value in compressor work of the amount of reheat.

3.5.11. *Rise in Temperature with Ratio of Extreme Pressures.* The temperature to which air will be heated by compression, if we neglect any cooling effect during this operation, is proportional to the initial absolute temperature* of the air. It increases also with the ratio of

*The absolute temperature is that indicated by the thermometer plus 461.2° Fahr.

the final absolute pressure to the initial absolute pressure. In ordinary compressors the pressure of the air drawn in is, on account of valve resistance, initially less than that of the outer air, so that in such machines the ratio of pressures, and therefore the final temperature, is greater than if the air filled the cylinder with atmospheric pressure. For the same reason air will be heated more by compression to the same gauge pressure above the atmosphere in higher altitudes than at sea-level. The formula expressing these relations is:

$$\left(\frac{p_1}{p_2}\right)^{0.2908} = \frac{T_1}{T_2}$$

In which p_1 is the initial absolute pressure, p_2 the final absolute pressure, T_1 the initial absolute temperature, and T_2 the final absolute

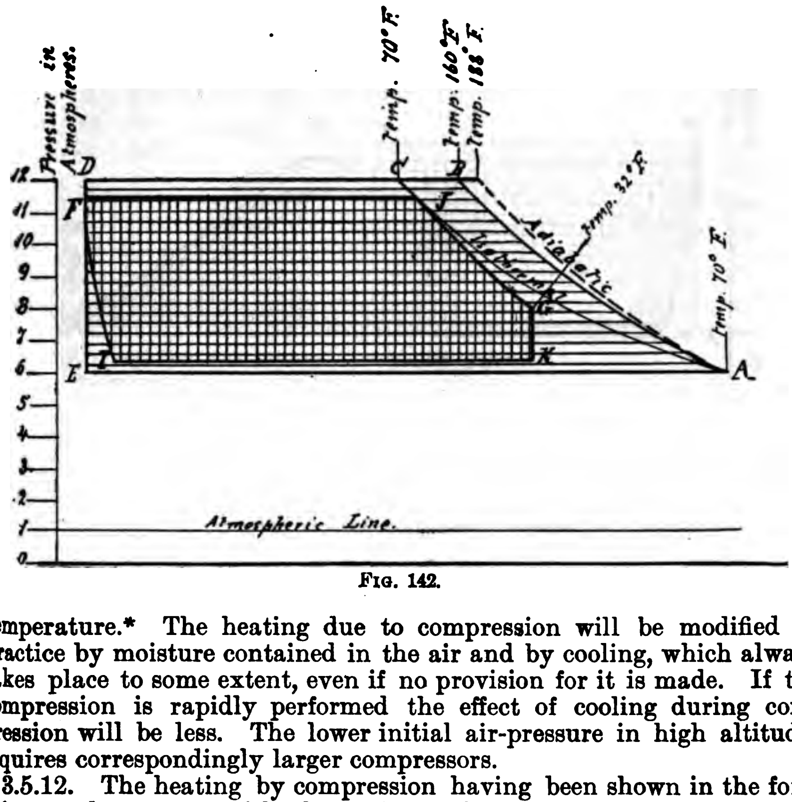


FIG. 142.

temperature.* The heating due to compression will be modified in practice by moisture contained in the air and by cooling, which always takes place to some extent, even if no provision for it is made. If the compression is rapidly performed the effect of cooling during compression will be less. The lower initial air-pressure in high altitudes requires correspondingly larger compressors.

3.5.12. The heating by compression having been shown in the foregoing to be greater with the ratio of final to initial pressure, it is natural to consider a reduction of this ratio. If, however, we should employ atmospheric pressure as the initial one for such reduced ratio, the compressor and air engines would require very large cylinders.

3.5.13. *The Cummings System of Compressed-Air Transmission.* Considerations like the foregoing have led Mr. Charles Cummings to devise a system of air-power transmission, in which the initial absolute press-

* Absolute pressure is gauge pressure plus atmospheric pressure.

ure of the air entering the compressor and the equal final pressure of the air leaving the engine are high, say 80 to 100 lbs.; while the final pressure in the compressor, or the initial pressure in the engine, are about twice this amount. These conditions necessitate a return pipe for the lower pressure, the compressor, air engine, and pipe-lines forming a closed system, in which the same air is used over and over again. The diagram, Fig. 142, shows by areas the relation of the work necessary to compress the air, to the work capable of being utilized in the air engine. The compressor work is indicated in horizontal, and that of the engine in vertical shading.

3.5.14. The weight of air required to pass the system per unit of time, for the same power, is greater in this system than when using the ordinary reheating system. As a result, the return pipe particularly

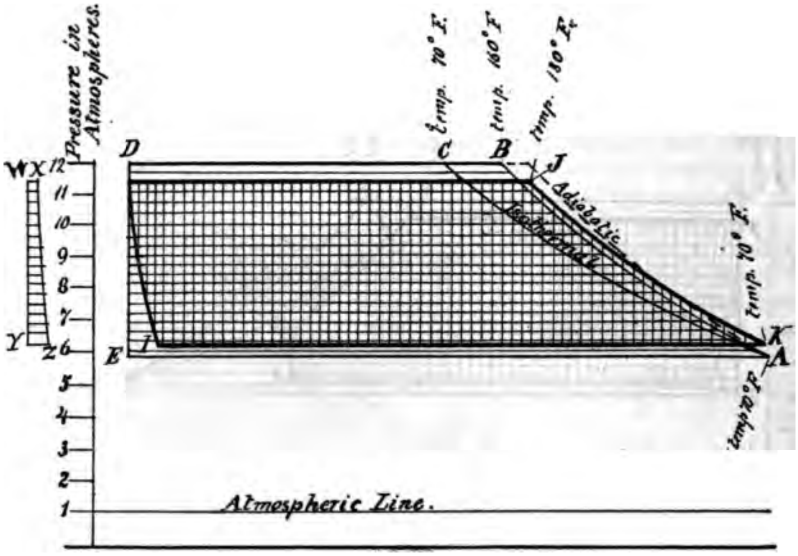


FIG. 143.

must be of larger size than the single pipe of the reheating system, if the velocity of air in the pipes be assumed to be the same in both cases. The power pipe-line will not vary much from that required for the reheating-plant, only in that it is subjected to higher pressure.

3.5.15. Notwithstanding the extra cost for transmission pipe, the Cummings system has very much to recommend it for operating pumps underground, especially where reheating would introduce complication. With it the advantages of compound compression and cooling during compression are much less marked than in the systems using initial atmospheric pressure, which permits dispensing with considerable complication. As the air cannot heat by compression beyond a moderate amount, the compressor can be allowed to run faster, and therefore be made of correspondingly smaller size. Reheating also permits increase of efficiency, though, on account of the originally high efficiency, it is of less proportional value than in the ordinary system. Fig. 143 shows the effect of reheating to the mechanically economic limit. The average pressure in the compressor and also in the engine varies less from the

extremes than in the atmospheric-pressure system. An incidental advantage is, that the pump engines, particularly if direct-acting, can be operated under water until they give out. This feature adds a valuable guarantee to the safety of the mine. The compressor and air engine are cheaper, but the transmission pipes are more expensive than in other systems. To properly estimate the value of this system it must be compared with the reheating system as to mechanical efficiency, first cost, and simplicity of construction and manipulation.

3.5.16. *Compressed-Air Pump Engines.* The pump engines driven by compressed air are similar to those driven by steam. Lubrication of slide-valves is somewhat more difficult if the air is reheated. Puppet-valves would probably be better for reheated-air engines. Rotative fly-wheel engines are the ones adapted for utilizing the expansive work of the air. Direct-acting pump engines are, however, much operated by air, particularly the small pumps used in winzes and parts of the mine removed from the shaft, which are nearly always operated by this means. Air-driven station pump engines can be regulated in the same manner as steam engines by control of the air supply from a float in the station-tank.

3.5.17. *Reheaters.* These may be designed for heating by direct fire or by steam. The latter would be the most convenient underground. They should be arranged with the pipes so that the steam travels a considerable distance in them while the air travels in a course opposite to that of the steam. This gives the best possible effect of heat expended. The water of condensation should be removed automatically by a trap at the lower end. In the compressed-air pumping-plant at the Magalia Mine, Butte County, California, the air is reheated close to the pump by steam conducted down the shaft. Reheating at the surface is the method adopted at the North Star Mine, Grass Valley, and the air-pipe is covered by non-conducting material to retain as much of the heat as possible.

3.5.18. On first thought it may appear to many that the steam might be used to better advantage in driving a pump engine than to reheat air, but this is not the case, because the steam parts with its latent heat of vaporization in heating, nearly all of which heat can be converted into work in the air engine, which is not possible in the steam engine. In reheating compressed air the steam is used about five times as efficiently as in performing work directly. Where an air engine is operated at no great distance from the compressor, and where the latter delivers the air at a considerable temperature, it may be possible to keep the heat in the air by non-conducting covering applied to the pipe. In this way good efficiency could be realized without reheating.

3.5.19. *Receivers.* Long air-pipes serve in a measure as receivers and storage for the compressed air. Separate receivers are, however, generally also located near the compressor at the surface, and sometimes near the engine underground, to serve as regulators. (See 1.2.60.) They serve incidentally also for trapping part of the moisture contained in the air. They should be fitted with a waterglass to indicate the level of this water, a pressure-gauge, safety-valve, and means for draining off water.

3.5.20. *Compressors.* Compressors must adapt their output to the requirements of the underground machinery. For this reason they have to operate at all speeds, and frequently must stop altogether. Their regulation in this respect is made dependent upon the air-pressure in the receiver, which, by suitable mechanism, causes a shutting off of the power supply and slowing down of the compressor when the pressure rises above a given limit, and inversely causes an increase of power supply and speed when the pressure falls. Where the draught upon the compressor is so irregular that it has to stop frequently, a duplex compressor presents the advantage of being self-starting.

3.5.21. The irregular duty and speed of the compressor are much more favorable, as regards mechanical efficiency, for operation by steam than by water-power. This may affect the choice of power where the water has to be bought. It is, however, to be remarked, that for pumping the work is generally more regular than for hoisting or rock-drilling, and where a separate compressor operates the pumps, it may be possible to utilize water-power with some degree of efficiency.

3.5.22. Water-injection cooling is much less employed now than formerly. If water is used in the compressor-cylinder, it should be perfectly clean, otherwise the cylinder will soon wear out. It is generally difficult to obtain clean water in mining regions. If so much water is injected that the temperature of the air is kept down to 20° or 30° above that which it had on entering, there is quite an amount of work required to force in the larger volume of water, for which no useful returns are had. As the volume of water injected per stroke is liable to be greater than that of the clearance space, the speed of the compressor must be kept lower than where no injection is used, to avoid risk of breaking the compressor-heads. Another objection to the use of injection-water is that it interferes with lubrication by floating the oil away from the rubbing surfaces.

3.5.23. The volumetric effect of a compressor is reduced not only by the resistance of the suction-valves, but also by the heat of the metal of these valves and passages, which impart some of this heat to the air drawn in on the suction-stroke, causing it to expand and thereby fill the cylinder with a volume of air of less weight and higher temperature. The effect is a double one: first, a lowered output of the compressor, then a higher final temperature due to compression, both these combining to lower the efficiency.

3.5.24. A high-class, modern, steam-operated, compressed-air pumping-plant will compare favorably in commercial efficiency with underground steam pumping-engines. The high-duty steam pumping-engines, whether rotative or direct-acting, are more expensive than those which give good efficiency when operated by compressed air. The former also require more and better attendance, which increases the operating expense if there are pumps, as is usual, at several points in the shaft. It is also possible to use a larger engine at the surface, which can be more easily made of high efficiency than underground engines, particularly if the underground machinery is cut up into several units.

CHAPTER VI.

Pumps Operated by Attached Hydraulic-Pressure Engines.

3.6.01. Hydraulic operation of underground pump engines may be accomplished in several ways. Firstly, the pumping-engines underground may be directly operated by a natural head of water, the engine

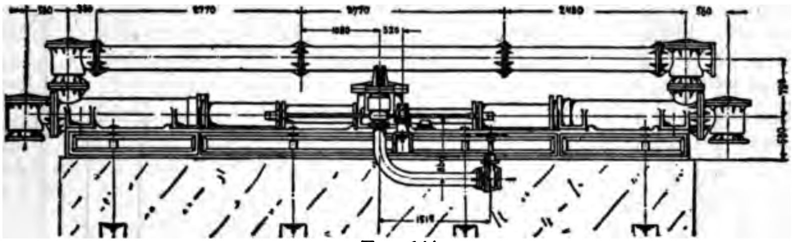


FIG. 144.

delivering the spent power-water, together with the mine-water, at the point of discharge. Secondly, the pressure necessary to drive the underground hydraulic pumping-engine may be artificially generated, either entirely or as supplemental to an insufficient head, by a steam engine driving pumps at the surface. In this case, also, the power-water is

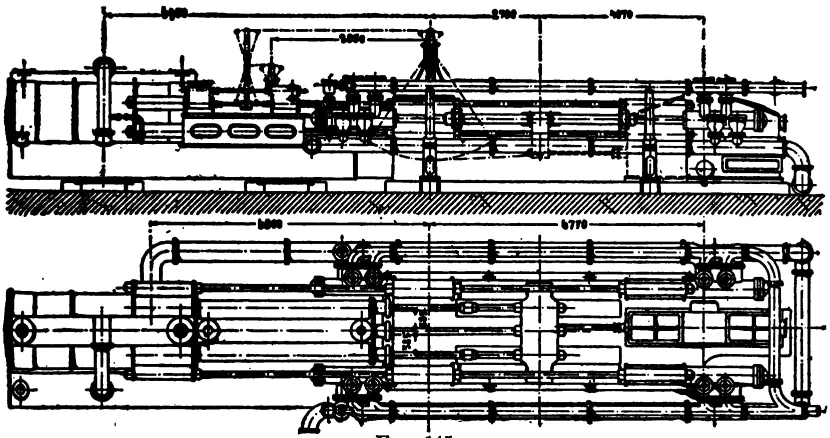


FIG. 145.

delivered, together with the mine-water, at the point of discharge, but if this point is at the surface, the power-water may be used over and over again. A third method of operation, different from the two foregoing ones, is by means of the so-called hydraulic pumprods. In this plan one or two columns of water are reciprocated by a valveless pump driven by a prime-mover, and impart corresponding motion to a piston or plunger connected with the mine pump.

3.6.02. *Hydraulic Engines Controlled by Valves.* The underground hydraulic engines employed to operate pumps in the manner first named are similar to those used at the surface for working pumps through rods, except that the pump-plungers are directly connected to

the plungers or piston-rods of the engine. Fig. 144 illustrates the Davie hydraulic pumping-engine, which is of this class. A modification of this type was used in the Combination shaft, Virginia City, Nev. The pumps at the lowest level raised the water over 1,400′ to the level of the Sutro Tunnel. There were two independent pumping-engines at the station, each capable of making, at a maximum, about ten

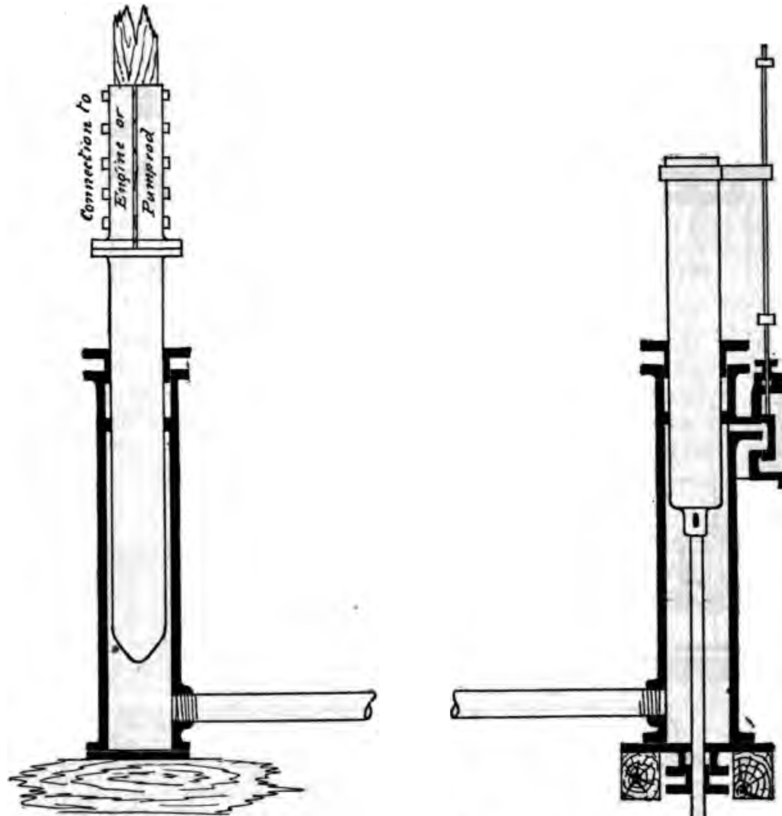


FIG. 146.

single strokes per minute. An interesting fact is said to have been noticed when both engines were running, namely: that they would adjust themselves to make their strokes in rotation. This might be explained by the inertia of the water in the driving-column. Air-chambers were not used at first, but were found necessary, on account of the frequent breakage of pipes.

3.6.03. The hydraulic pumps of the Combination shaft at first were operated by artificial excess of pressure of about 1,000 lbs. generated by a steam engine driving pumps at the surface and forcing the water into an accumulator-chamber charged with compressed air. The surface pumping-engine was of the Davie type, and is illustrated in Fig. 145. By this arrangement the pressure-water was used over and over again, but the expense of operation is said to have been over $6,000 per month, while the excessive pressure caused frequent breakages. The natural

pressure of the city water was afterwards used to drive the pumps, and the total cost of operation, including that of power-water, was reduced to about $1,000 per month. The plant was perhaps the largest hydraulic mine pumping-plant ever built. Its first cost amounted to about one quarter of a million of dollars. The Knight hydraulic pumping-engine described in 2.5.37, 2.5.38, and 2.5.39, and illustrated in Fig. 116, could also be coupled directly to underground pumps.

3.6.04. *Valveless Engines.* An example of the hydraulic rod system, though not operating a direct-acting pump-engine, exists at the New Almaden Quicksilver Mine, Santa Clara County, California. Fig. 146 illustrates the principle of the arrangement. It is a horizontal transmission, and therefore requires only a single reciprocating column, the weight of rod and other parts being sufficient to accomplish the return-stroke of the water-column.

3.6.05. Where there is no weight of pumprods or other parts to be raised, and also where the transmission is vertical, two balanced reciprocating columns of water are used.

3.6.06. No admission- and discharge-valves are required with engines operated by reciprocating columns of water, nor with the plungers used to reciprocate the water. It is, however, necessary to keep the volume of water in the reciprocating columns constant, so that the stroke of the underground engine and pump will not exceed the proper limits at either end. Leakage will reduce the amount of water in the columns, and this must be made up by forcing in a small quantity, either with each stroke or continuously. As it is not possible to adjust the quantity to be added so as to be exactly equal to the leakage, it is necessary to force in an amount slightly greater than the leakage, and to get rid of the excess by causing the underground engine to open a valve at the end of the stroke whenever this passes the prescribed limit. By adjusting these valves so that the volume swept through by the working piston or plunger of the underground pump will be somewhat less than that of the driving-pump at the surface, the latter can draw in the necessary replenishing water during the suction-stroke through a small suction- or check-valve. In the single-column hydraulic transmission, illustrated in Fig. 146, and referred to before, the stroke of the underground engine is regulated by admitting a small quantity of water under greater pressure than that existing in the pump, by means of some such arrangement as the slide-valve at the side of the working-barrel. The same arrangement permits the escape of a small quantity of water near the upper end of the stroke. The slide-valve is shown to be operated by means of a tappet-rod from an arm at the top of the plunger.

3.6.07. *General Remarks.* Hydraulic-pressure operation of pumps requires, in most cases, very expensive plants for any considerable depth, as the parts have necessarily to be made heavy so as to resist not only the static pressure, but also the strains due to water-ram. In the matter of water-ram, the artificial-pressure systems are in a better position than those employing a natural fall, because the mass of water moved and arrested is less. Where two hydraulic engines are supplied with pressure from the same column, and are operating so that their strokes occur in rotation, the column of water is kept continuously in motion, and the danger from water-ram is much reduced; so that in general, the engines can run faster under such conditions.

3.6.08. Hydraulic pressure is not suitable for sinking purposes, except perhaps for moderate depths, and in such cases generally artificial pressure will be better adapted, because the pressure can be suited to the increasing depth.

3.6.09. Clean water only should be used, but drain-cocks should be fitted at points where sediment is likely to accumulate in the engine. Plungers are much preferable to pistons, for the same reasons as with pumps.

CHAPTER VII.

Pump-Stations.

3.7.01. The stations for direct-driven pumps require a greater amount of excavation than for Cornish pumps, because they have to accommo-

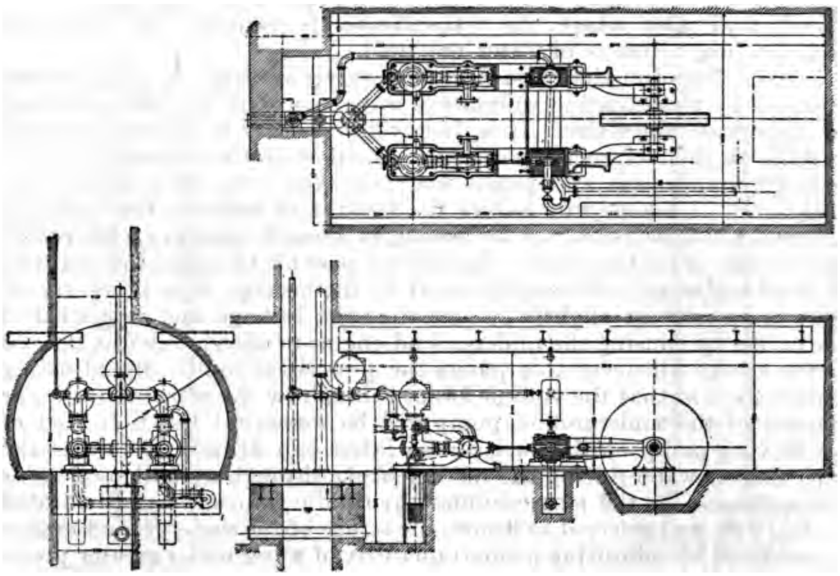


FIG. 147.

date the pumps as well as the tanks, and must also leave room to get around the pumps conveniently. Where several large pumps are in one station, and the latter is in ground requiring support, it is generally best to arrange the pumps in line and not side by side, so that the station assumes more the shape of a tunnel, in which the ground can be more easily and cheaply supported.

3.7.02. If the rock is very hard, so that the excavation cannot be extended at a later period without blasting, it is a good plan to excavate it larger than required at first, so that additional pumps can be quickly added in case of requirement.

3.7.03. The tanks are often placed below the pumps, as in Figs. 138 and 147. They should, if possible, be large, to afford a chance for settling of sand. Fig. 147 illustrates a pump-station with rotative pumps at the mines of the Boston and Montana Gold and Silver Mining Com-

y, of Butte, Montana. In the pump-station of the Crown Point ine shaft, at Virginia City, Nevada, shown in Fig. 148, the tank was ed at a level above the pump.

7.04. The facility with which direct-driven pumps can be regu-

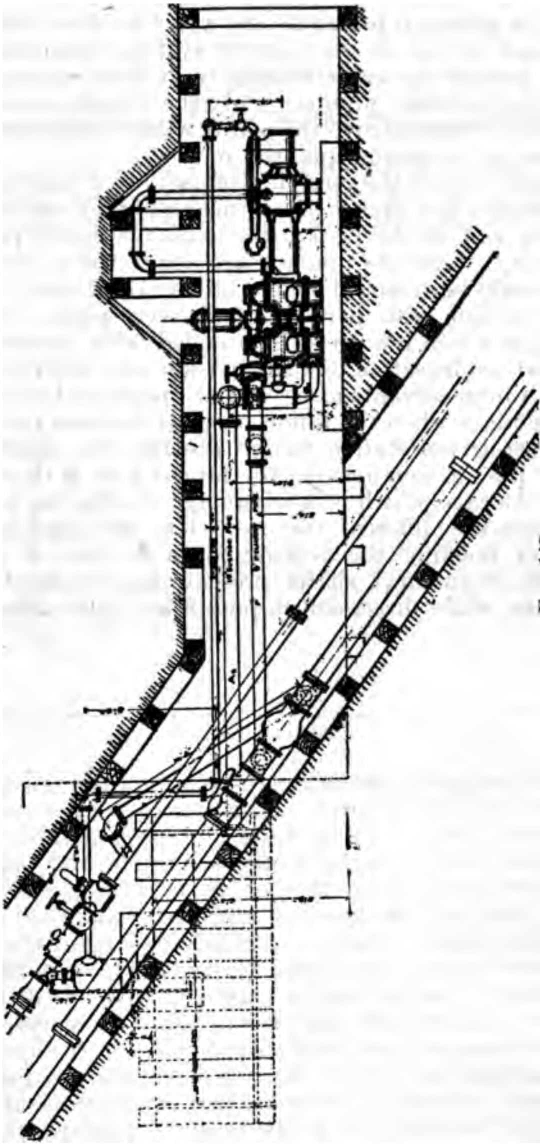


Fig. 148.

d, so as to adapt their work without great reduction in efficiency to inflow of water, constitutes, where pumps have to be used at different ls, one of the most striking advantages over the rod-pumping sys- s, in which, as described in 2.4.12 and 2.6.03, the relative regulation he pumps is effected by returning a part of the water pumped by

those pumps for which the speed is greater than required, but whose speed is necessarily the same as that of the pump having the greatest quantity of water to handle.

3.7.05. As direct-driven pumps can be constructed for very high lifts, the capacity of pumps at any station within the limits of admissible lift need only be sufficient to handle the water received into the tank at that station, and not, as in the Cornish system, arranged so that the upper pumps handle the water coming in at their stations, as well as that supplied by the lower pumps. Only the column-pipe and power-pipe have to be increased above the points where the pumps connect, to adapt the pipes to the greater quantity of flow.

3.7.06. Subdivision of the pumping capacity of a station is generally advisable, as it affords a chance of making repairs on one of the pumps, while the other can be forced a little to do the entire pumping duty during this time. Where two pumps are connected to cranks at right angles, they should be arranged so that either one of them can be cut off from communication with power- and delivery-pipes. With steam-driven pumps, in which low speed is attended with greater steam loss from the initial condensation, the subdivision into several units affords the chance of a more advantageous rate of operation by shutting down one part of the plant when the inflow of water becomes reduced.

3.7.07. Direct-driven station pumps obstruct the shaft only to the extent of their piping, thus leaving the largest part of the shaft free for the operation of a cage, which is of advantage in affording rapid communication between the different stations. The free space in the shaft is also needed for hoisting the sinking-pump in case of requirement. Crooked, small, or inclined shafts present disadvantages to the rod-pumping system, while direct-driven pumps are little affected by such conditions.

SECTION IV.

CHAPTER I.

Underground Geared and Belted Crank-Driven Pumps.

4.1.01. These are chiefly used where electric motors, or waterwheels under very high heads, constitute the driving power, though they can also be operated economically by steam or air engines. Electric motors

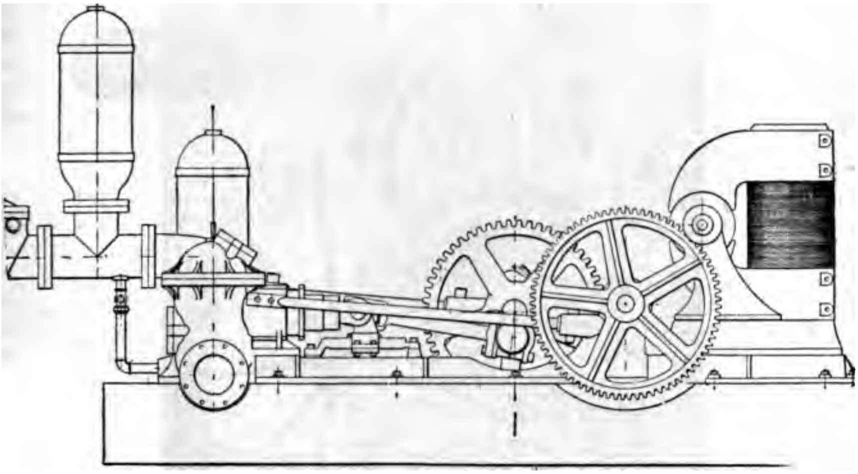


FIG. 149.

and waterwheels used underground generally require to make a great number of revolutions per minute. Although the short-stroke pumps employed permit a greater number of revolutions than those of long stroke, pumps driven by these two kinds of motors must generally be compound-geared, as the electrically-driven pump shown in Fig. 149, in order to get the proper reduction to the speed admissible for the pump.

4.1.02. It is important that the resistance during one revolution of the pump-crank be as uniform as possible, where waterwheels or electric motors furnish the driving power; otherwise, the power will be applied with loss of efficiency. For this reason such pumps are usually of the duplex or triple form. The duplex form may be used where the pumps are double-acting, like piston pumps, or differential plungers, as in Fig. 128. The most uniform resistance is afforded by the triple, single-acting, plunger pump, a type of which is illustrated by Fig. 150. This arrangement gives six maxima and six minima of pressure during one revolution, the maxima being only about 5¼% above the average pressure, and the minima, which are of shorter duration, 10½% below it. A flywheel mounted on the rapidly revolving motor- or wheel-shaft would further aid in equalizing the resistance. Belt-driven pumps

should also have a very uniform resistance, so as to prevent the wh
ping of the belt, which hastens its destruction.

4.1.03. The high-speed gears should be carefully cut in a gear-cutt
The pinions should, if possible, be made of more durable material th
the gear, because the teeth are subjected to greater wear. Rawhide

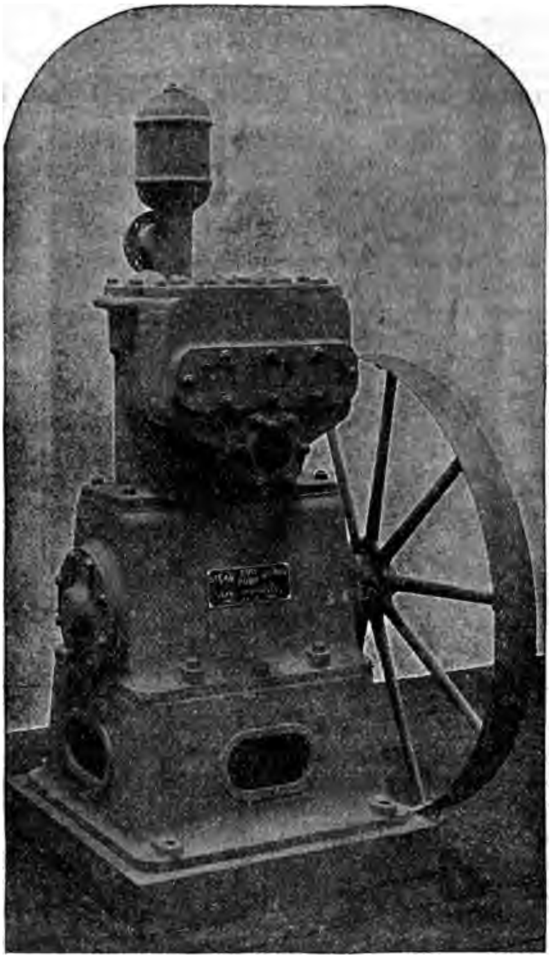


Fig. 150.

bronze pinions are generally used on the armature- or waterwheel-sha
Sometimes also the gear driven by a high-speed metal pinion is ma
with wooden cogs, as in Fig. 151. For the slow gearing, double-an
teeth (as in Fig. 152) are, if well made, the best, because they can
of finer pitch for the same strength. The finer division, and also t
continuous contact on the pitch line, cause such gears to run with ve
little noise. If, however, angle-tooth gears are badly made, so that,
example, the angles of the teeth do not lie in the same plane of ro
tion, then such gears are worse than simple spur gears, because th

l be thrown from side to side as they revolve and cause noise in rking. For operation by steam or compressed-air engines, which ke a less number of revolutions than either waterwheels or electric

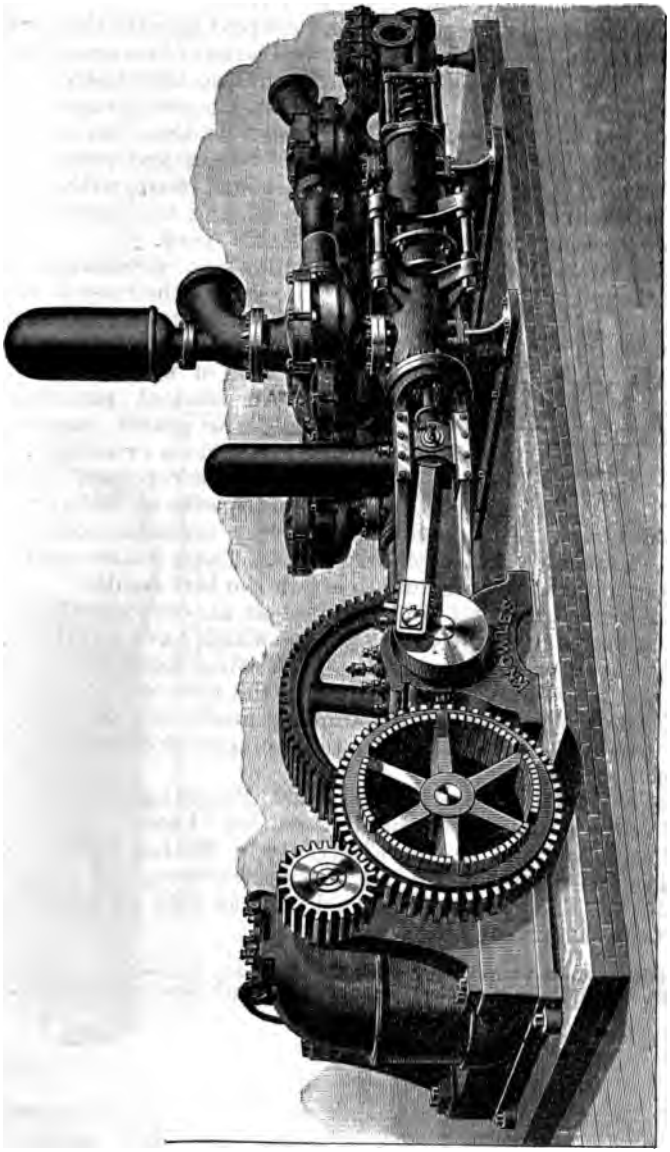


Fig. 151.

tors, the pumps are either single-geared or only driven by belts on a lley fixed on the pump crank-shaft.

l.1.04. Waterwheels used for driving pumps underground require a ıd much greater than at the surface, because they have to drive pumps ich must deliver at the surface not only the water of the mine, but o that discharged from the waterwheel. Such a method of operation

would therefore only find application for a moderate pumping-depth, and in this case the pumprod system would generally be preferable. There is, therefore, not much chance for the application of waterwheels to driving pumps underground.

4.1.05. As ordinarily constructed and coupled up with their driving-engines or -motors, the crank-driven pumps admit of no great variation in capacity. The crank-length is fixed, so that no adjustment of length of pump-stroke can be made. Electric motors cannot be varied in speed in very wide limits. With waterwheels it can be done, but not without very considerably reducing the efficiency. Steam and compressed-air engines, however, if of the duplex or compound form, with cranks at right angles, can be run at almost any speed, and are, therefore, better adapted for operating crank-pumps at variable speed.

4.1.06. Electrically-driven sinking-pumps are necessarily of the geared-crank type. The writer knows of no case of their use in practice. They would scarcely seem to be adapted to the hard usage to which they are subject in this kind of work.

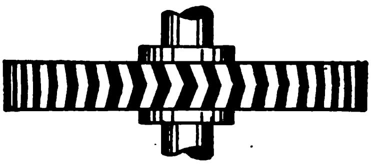


FIG. 152.

4.1.07. An efficient pumping-plant can be made with geared pumps driven by high-duty engines or motors. Some three-crank plunger pumps have been run at piston speeds of 460′ per minute without water-ram. This is due to the very uniform motion of the water in the suction- and discharge-pipes. Large valves and proper air-chambers naturally contribute to attain the best results.

4.1.08. Electricity is not well adapted as an economical means of transmitting power to reciprocating pumps which have a variable duty, unless they can be run intermittently, permitting the water to accumulate in large reservoirs or tanks during the time of stoppage. The method of applying electricity to pumping machinery will have to be much improved before it can bear out the claims of efficiency made by electrical companies.*

4.1.09. The XIIth Report of the State Mineralogist, published in 1894, contains an interesting chapter, entitled "Electric Power-Transmission Plants, and the Use of Electricity in Mining Operations," by Thomas Haight Leggett, in which a few electric pumping installations are mentioned. The reader is referred to that ably written article for further details on this subject.

* Two electrically-driven pumps are in use at the Golden Banner Mine, near Oroville, Butte County, California, where other electrical appliances have been installed.

SECTION V.

BAILING-TANKS.

5.1.01. The simplest method of raising water from deep mines is by means of bailing-tanks, which may take the water either from station

FIG. 153.

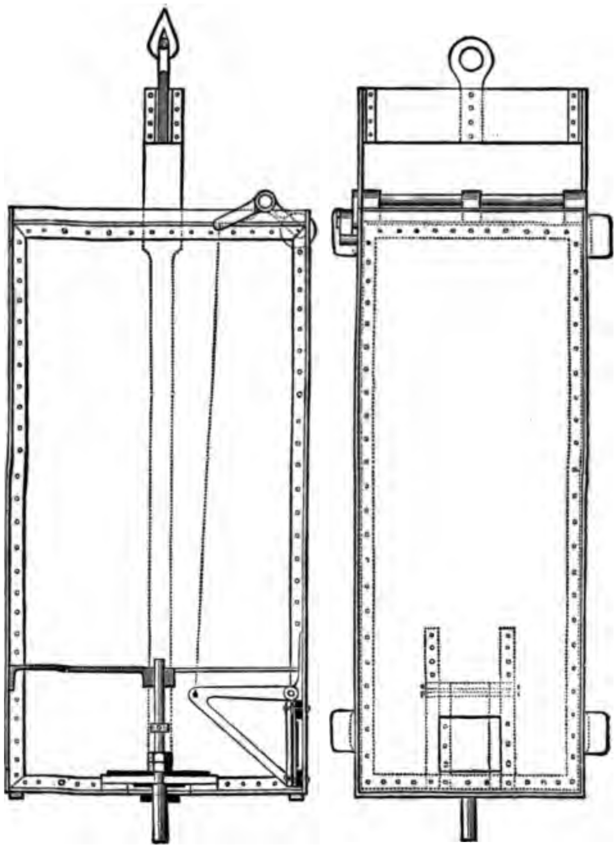


FIG. 154.

reservoirs or from the sump. In the latter case they are either made self-filling or are filled by means of pumps or other contrivances. Rapid filling of bailing-tanks is very important. Figs. 153 and 154 illustrate types of tanks fitted with a valve in the bottom, which opens of itself when the tank sinks into the sump-water. Such a method requires a considerable depth of sump in order to fill them, and tanks are therefore not adapted for sinking purposes unless an artificial method of filling them is used. Means for thus filling the tank may be movable

steam or compressed-air pumps, injectors, or pulsometers. These should be of ample capacity so as to fill the tank as rapidly and with as little delay as possible. The bailing-tank in this method need not approach quite to the bottom, so as to cause no interference with the other operations of sinking. Since, however, in case of a considerable rate of inflow, the water may rise in the intervals of the trips of the bailing-tanks to such a depth as to interfere with the other work, an artificial sump is sometimes used. This consists of a tank suspended in the shaft and sufficiently larger than the bailing-tank, to admit of the latter dipping entirely into it for the purpose of filling itself. Pumps or other water-raising appliances can then be operated continuously to raise water into the artificial sump, thereby keeping the bottom of the shaft as free as possible for the men to work. The artificial sump is periodically lowered as the shaft goes down. This can be most quickly accomplished by attaching it to the bailing-tank. Fig. 155 shows a double arrangement of bailing-tanks and artificial sumps for a very large circular shaft like those used in Europe. In the case illustrated the artificial sumps are suspended by cables from the surface, which serve also as guides for the bailing-tank.

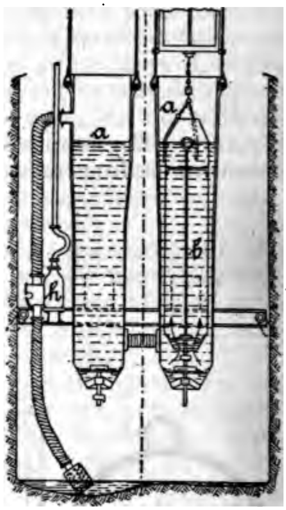


FIG. 155.

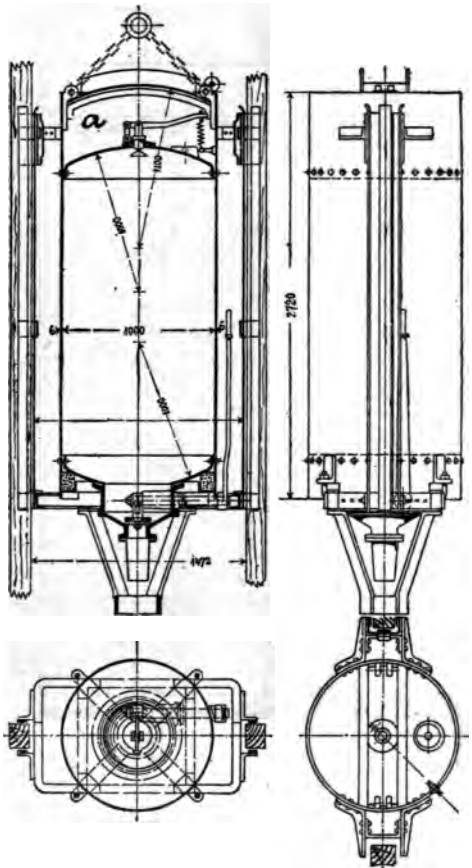


FIG. 156.

5.1.02. Bailing-tanks are usually made of iron. Square wooden tanks, held together by bolts, are sometimes constructed at the mine for an emergency. They are not very durable. Bailing-tanks on the Comstock were sometimes very large, some holding about 150 cu. ft. Sometimes bailing-tanks are suspended below a cage. In such cases they should be fitted with safety-catches, so that the cage-catches will not be called upon to catch the combined load of cage and tank.

)3. *Vacuum-Tank.* An interesting and presumably efficient
d of filling a bailing-tank rapidly was suggested by Mr. Bacher
sinking of the Max shaft at Kladno, Bohemia, referred to before
paper. The bailing-tank is illustrated in Fig. 156, and is called
um-tank. It consists of a closed vessel, which is filled with steam
surface in order to expel the air, and to cause, by its subsequent
isation, a sufficient vacuum to draw in water, and thus fill itself
stance above the sump. The bottom of the tank has an opening
by a valve, and communicating with a suction-hose of suitable
. When the tank arrives at the surface the discharge-valve at
ttom is opened by means of the lever at the side, and at the same

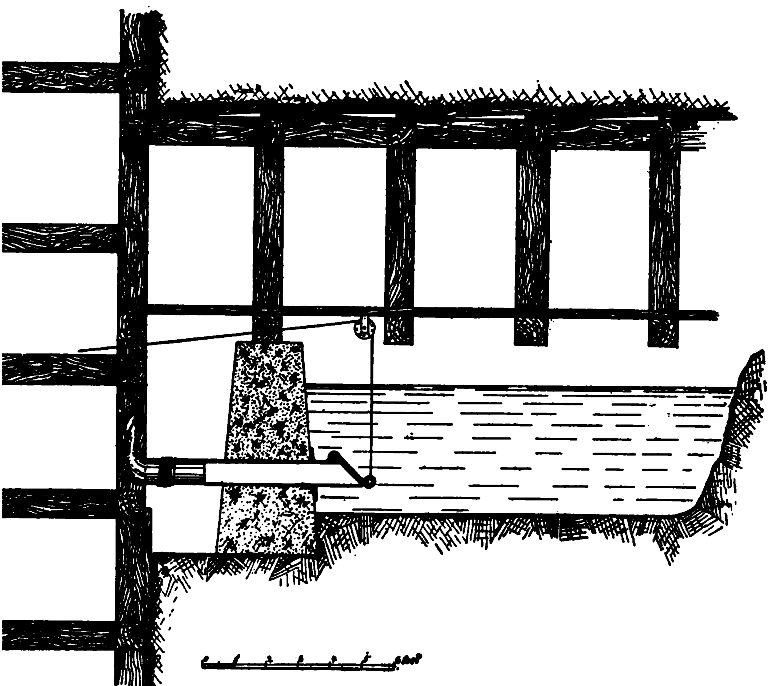


FIG. 157.

ie steam supply is coupled on at the top of the tank, so that the
re will aid in expelling the water more rapidly. As soon as steam
at the discharge both openings are closed, and a valve, communi-
with the small reservoir of water, *a*, at the top of the tank, is
l to admit a spray for condensing the steam. Arrived at the bot-
e lower valve at the upper end of the suction-hose is opened to
tank, and closed again before the tank starts to the surface.

)4. *Bailing-Tank Stations.* Where the water is taken from some
higher levels, reservoirs or tanks are built to collect the inflow at
)int. The reservoirs are fitted with a discharge-pipe carrying a
)n the inside, which is operated by a rope and communicates with
iarge-hose to lead into the bailing-tank on the outside. Fig. 157
ites a reservoir formed by a masonry bulkhead placed across an
tion, with the discharge-pipe built in.

5.1.05. *Tank Discharges.* The discharge from bailing-tanks at surface or at a drain tunnel must be effected in such a manner t none of the water will fall down the shaft again. The ordinary wa buckets used in small workings are drawn aside and the water sim poured out. The bucket in Fig. 153 has a downwardly projec stem on the valve, which strikes the floor and lifts the valve when

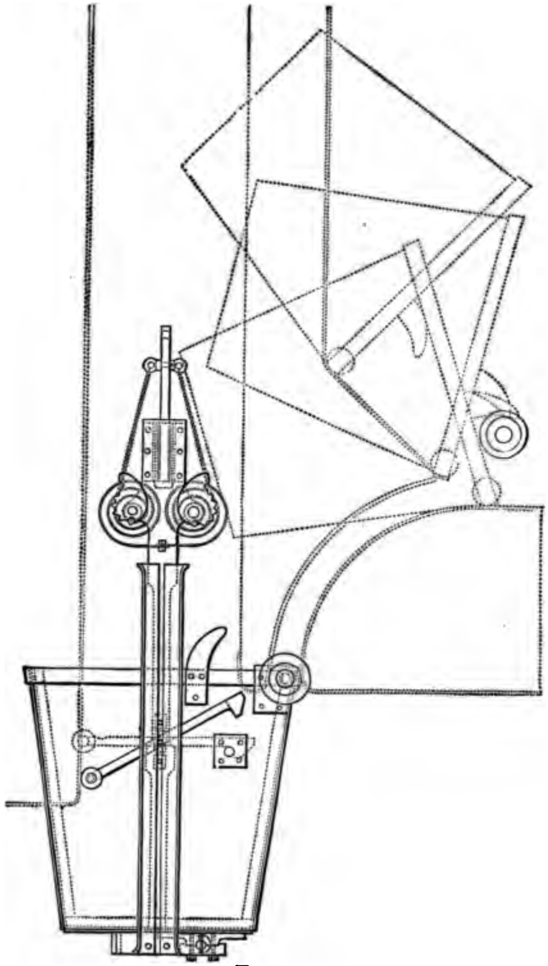


FIG. 158.

bucket is lowered into the discharge-sluice, thus permitting the wate escape. Bailing-tanks guided in vertical shafts usually have s valves like in Fig. 154, and these sometimes have attached a l which leads the water into the discharge-sluice; or a short sl mounted on rollers is pushed under the tank to conduct away its charge. In inclines the discharge of the tank can always be brou over the sluice or tank without any other arrangements.

5.1.06. The most rapid manner of effecting the discharge of bail tanks is to construct them like skips, so that they will dump a

atically as they are hoisted above the collar of the shaft. Fig. 158 ows a self-dumping skip for a vertical shaft, which is used for hoistg both rock and water. Fig. 159 illustrates a simple skip used for clines. The manner of effecting the dumping appears readily from the lustration.

5.1.07. As a permanent method of controlling the water of a mine, iling is generally economical only for smaller quantity inflow. Such conditions prevail at some of the mines the Mother Lode, in Amador County, California, as at e Kennedy Mine, before referred , where the water amounts to about 5,000 gals. per day during the dry ason, and about double that amount uring the wet season. For large caacity, bailing is justifiable only as n emergency measure to supplement mps during their repair, or to aid em temporarily during a large inux, or, as in the case of the Susque-

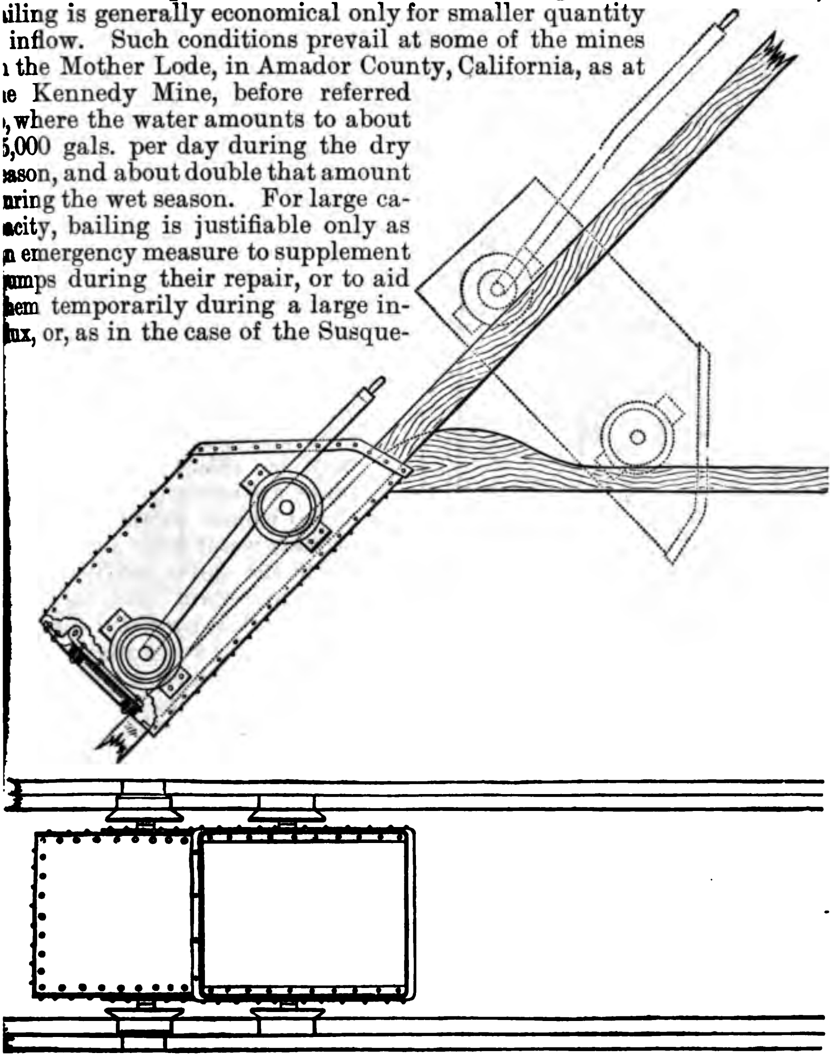


FIG. 159.

nna Coal Company's mines, to rapidly drain a flooded mine with the ge hoisting-plant on hand; bailing-tanks being in this case most rapidly t ready, and the method being also the most economical on account the small first cost of plant and the short period that it would be uired to be used. The details of construction and method of operatg are shown by Figs. 160 and 161, and the following more detailed

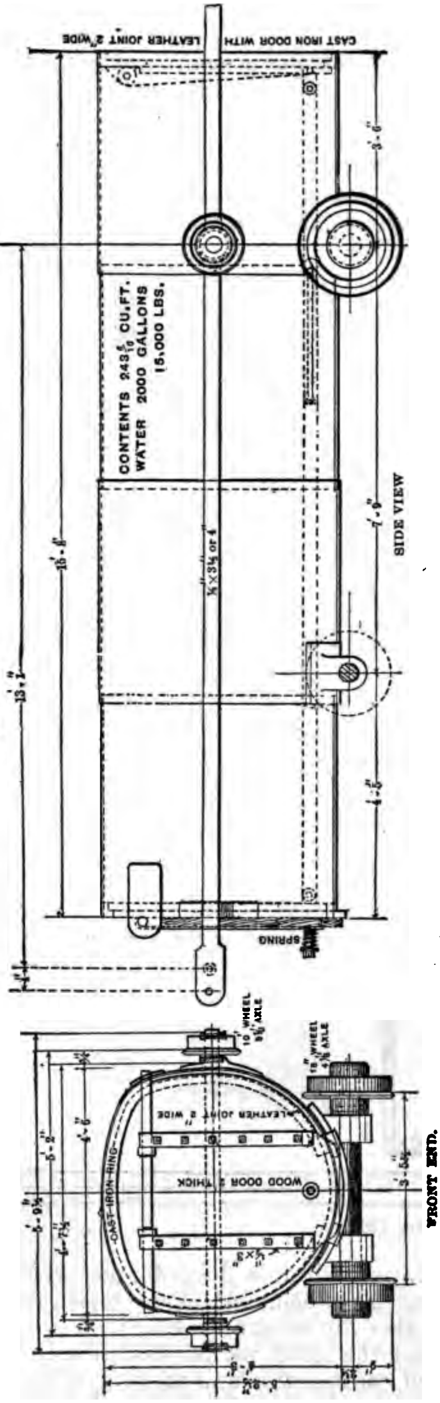


FIG. 160.

description. At the end of each tank is a large iron door of almost the full size of the end of the tank, opening inward, so that when immersed the tanks fill almost instantly. To provide for holding the water while it is hoisted up flat pitches, a wooden door is attached to the front of each tank, opening outward. Each front door is attached to the door at the back by an iron rod, provided with a sliding link, so that the back door can open independently of the front, but the latter is held closed as long as the rear door is closed. This connecting rod, as shown in Fig. 160, passes through the front door and through a spiral spring in front of it, so that the amount of pressure necessary to keep the water from leaking out may be readily applied. The tanks are mounted on self-oiling, closed wheels, so arranged as to exclude water from the bearings while the tanks are immersed, and to retain the lubricant. Each tank is provided also with side-wheels, vertically over the rear axle, which have a gauge sufficiently wide to clear all other portions of the tank; and on the surface an elevated track is provided, upon which these dumping-wheels run and thus raise the rear end of each tank as much as may be necessary to dump the water into a trough between the tracks, the tilting forward of the tanks opening the back door and releasing the front one. The tanks while emptying rest on their forward wheels and on the dumping-wheels. By having the tracks at the surface slightly up-grade, the tanks will run back when empty, as soon as the rope is slackened. To allow this dumping, the hoisting-rope is attached to the tanks by a yoke reaching

ck on the sides and pivoting on the axle of the dumping-wheels, the nks back of the first one being attached by eye-bars reaching from de to axle of the dumping-wheels on the tanks. A stop is provided,

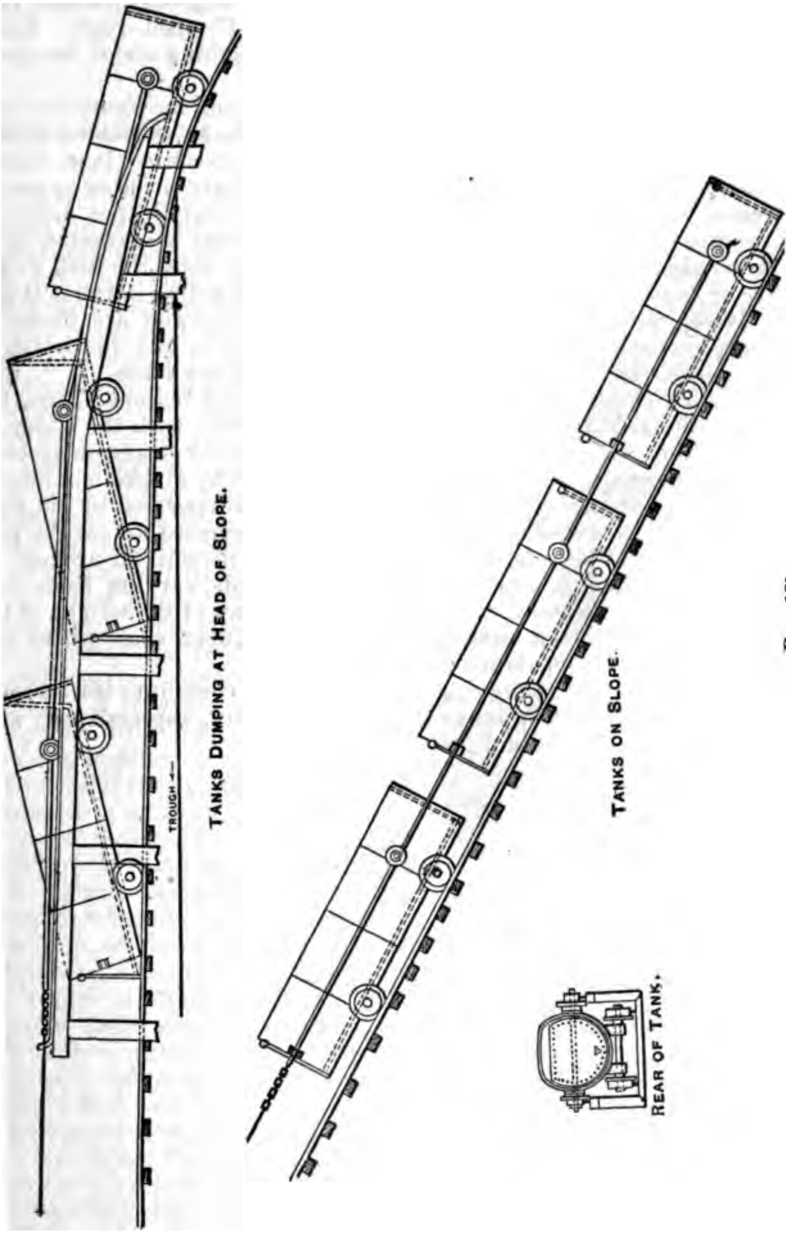


FIG. 161.

prevent the yoke on the forward tank from dropping and catching in track when the rope is slackened. This plan of "tandem tanks" s designed and used to hoist about 25,000,000 gallons of water which

had been admitted to extinguish a mine fire in one of the Susquehanna Coal Company's mines. The slope was small in section, and 3,200′ long, with single track, and with pitches varying from 4° to 20°. The hoisting-plant consisted of a pair of 26″x 60″ direct-acting engines with cast coned-drum, 9′ to 12′ in diameter, carrying $1\frac{5}{8}''$ steel rope. These engines had been previously hoisting five cars, weighing about four tons each when loaded.

5.1.08. Bailing appliances should be in readiness for immediate use at every mine operated through shafts or inclines, to relieve or aid pumps. This fact, and the necessity of being able to control large bodies of water, have an important bearing on the necessary hoisting capacity of a mine. This should generally be adequate to handle not only the rock and ore output, but also all the water that may be expected to be encountered. With deep mines the hoists should raise the load to the surface as rapidly as possible, and the use of direct-acting hoists is therefore advisable. In inclines which follow the vein, and are therefore generally crooked, rapid hoisting is not admissible, and the hoisting engine should then be capable of handling very heavy loads.

5.1.09. Bailing is deficient in economy for several reasons: First, the weight of the tank and cable must be raised, together with the water, at each operation; second, hoisting-engines, if operated by steam, on account of their frequent starting and stopping, being thereby alternately heated and cooled off, are not economical steam-users. If operated by air, they can work more economically, as long as the compressed air can be produced cheaply. Water-power hoists also are inefficient, on account of starting and stopping, and operating at all speeds varying from that required for best efficiency. The effect on economy of the weight of the tank and cable will not exist in those not frequent cases where two tanks are run so as to balance each other.

5.1.10. Gasoline hoisting-engines have of late come into use to some extent to operate bailing-tanks of small capacity, especially in arid regions or places where solid fuel is scarce.

SECTION VI.

CHAPTER I.

Pumps and Other Appliances for Raising Water from Moderate Depths in Mines.

6.1.01. *General Remarks.* Appliances for raising water to moderate elevations are useful in many ways for mining. They may be used in order to avoid too frequent moving of the heavy sinking-pump by providing a lighter low-lift apparatus, which pumps into an artificial sump provided for the sinking-pump, or they may pump into bailing-tanks, or into reservoirs from which the tanks are filled, as described in 5.1.01, so that no great depth of water is required to be maintained in the sump for filling the bailing-tank. The generally low efficiency of apparatus available for such purposes affects the total efficiency of the system but slightly, because the amount of low-lift work is small compared with the rest of the lift. Low-lift appliances also find application for draining open workings or levels in a mine, or in drift mines in which the channel rises and falls, or where the operating-tunnel has been driven too high. Where the water has merely to be raised over and dropped down the other side of an elevation less than the barometric height to which water will rise, siphons may sometimes be used. The siphon action should also be utilized to aid the pumps in all cases where water has to be raised over and dropped down the other side of an eminence. This is much more important for low lifts than for high ones, because the proportional reduction of total lift is greater. The machines which find application for the purposes mentioned are reciprocating pumps, centrifugal pumps, pulsometers, jet-lifters, air-lift pumps, and siphons. Some of these find application in mining chiefly in furnishing water supply, as for gold-washing, milling purposes, or for boiler use.

FIG. 162.

6.1.02. *Reciprocating Pumps.* These have been treated in fc chapters. For direct-driven, low-lift pumps it is necessary, how that the steam or compressed-air cylinder be the smaller in propc to the water cylinder, the less the height is to which the water has raised. Some of such pumps are single-acting, and utilize onl suction-lift, being, therefore, only adapted to pump to heights less that due to the pressure of the atmosphere. The wrecking pump s in Fig. 162 is of this type.

CHAPTER II.

Centrifugal Pumps.

6.2.01. Where large volumes of water require to be raised to mod elevations, centrifugal pumps are usually the cheapest, and, unde tain conditions, the most efficient machines. They are also well ad

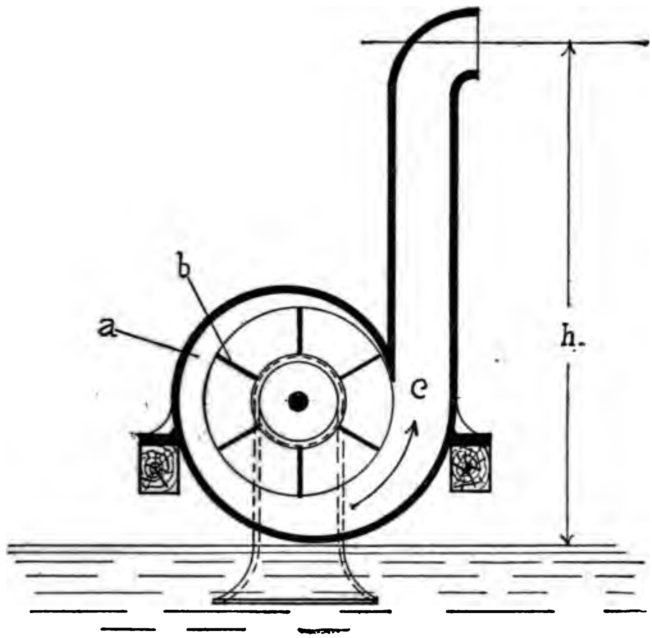


FIG. 163.

to handling muddy and sandy water, and may deliver gravel and cobbles just large enough to pass through them.

6.2.02. The action of a centrifugal pump may be best describe reference to Fig. 163, in which *a* is a casing, within which revolv paddles *b*. Assuming the pump to be primed and the casing to be with water, the latter will have imparted to it the rotary motion o paddles, by virtue of which centrifugal force or pressure is ex within the fluid, so that it will escape with that force at any outl at *c*. If the outlet communicate with an ascending pipe, the l will rise in it to a height determined by the amount of centrifugal The latter is the greater, the greater the circumferential velocity c

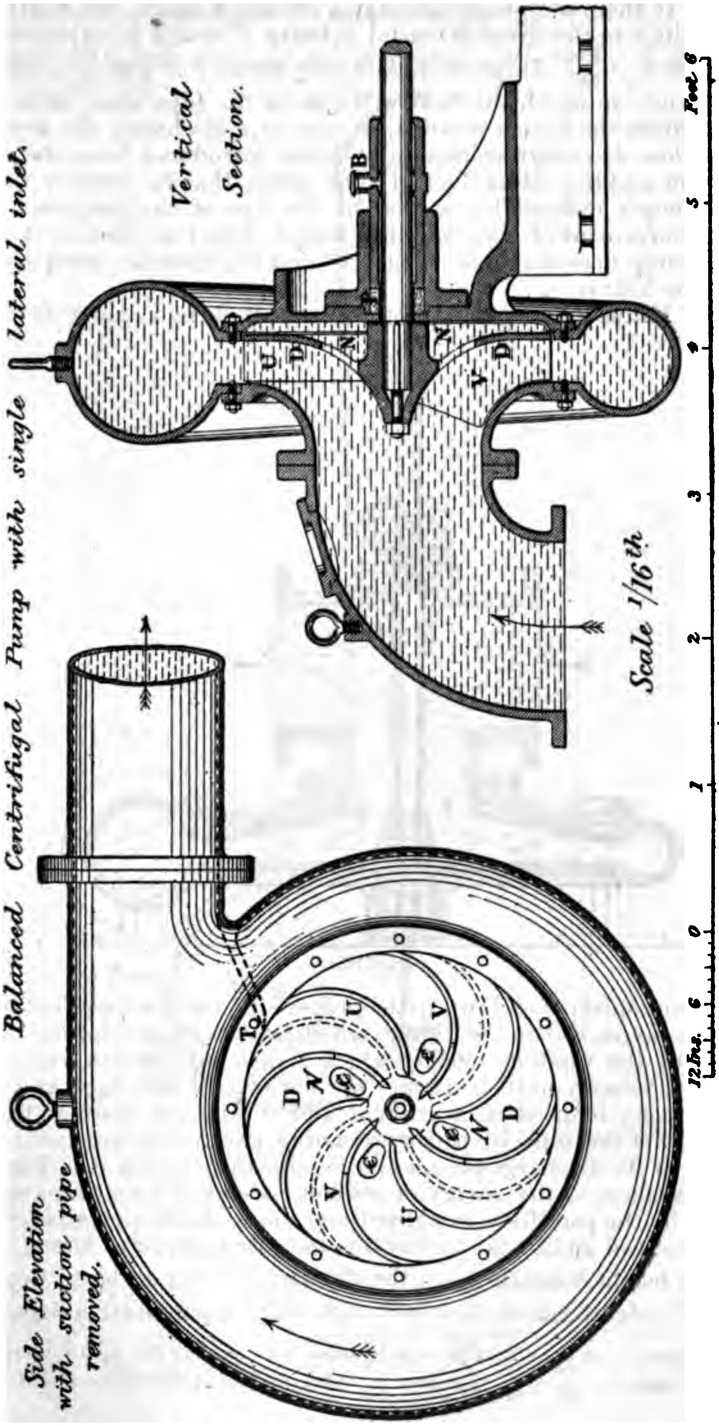

Balanced Centrifugal Pump with single lateral inlet.
Side Elevation with suction pipe removed.
Vertical Section.
Scale 1/16th
12 Ins. 6 0 1 2 3 4 5 Feet 6

FIG. 164.

paddles. If there were no unavoidable efficiency-losses, the relation of the total lift h to the circumferential velocity V would be expressed by the formula $h = \frac{V^2}{64}$. In practice, h is only about $\frac{4}{5}$ or $\frac{3}{4}$ of $\frac{V^2}{64}$. The lift h is the height to which the fluid will rise in the pipe when there is no discharge from the latter, or when, in case of a discharge, the liquid is caused to lose its energy of motion by being introduced from the space between the paddles into a duct of such width that its velocity will be suddenly much reduced below that of the tips of the paddles. This sudden enlargement of waterway is a feature found in most of the centrifugal pumps manufactured. Figs. 164 and 165 illustrate pumps which possess this feature.

6.2.03. Let us assume, on the other hand, that, by keeping the cross-

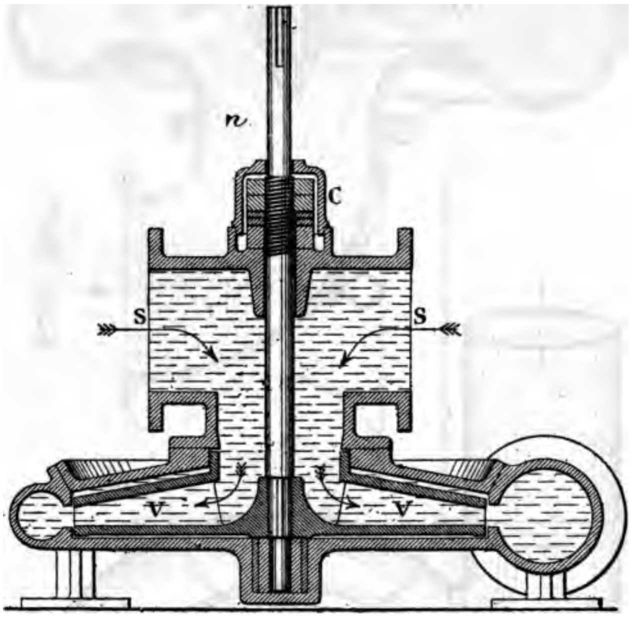


FIG. 165.

section of the spiral duct down to the proper size, the discharge is effected in such a manner that the liquid, which leaves the periphery of the blades with the rotative velocity which it has in common with them, retains this velocity until it reaches the outlet c of the duct, and then has its velocity reduced in a gradual and continuous manner to that admissible in the pipe by a corresponding gradual enlargement of a short part of the discharge-pipe, where it joins the duct, as at d, Fig. 166. In this case most of the energy of motion which has been imparted to the water by the paddles b, is utilized and changed into potential energy or pressure-head additional to that due to centrifugal force alone. This additional height h equals $\frac{V^2}{64}$, if the discharge-pipe is so large that the velocity is insignificant so that $h_1 = h$.* It is apparent, therefore, that

* If the velocity u in the discharge-pipe is taken into account the equations become $h = \frac{V^2}{64} - \frac{u^2}{64}$ and $H = \frac{V^2}{32} - \frac{u^2}{64}$. The term $\frac{u^2}{64}$ is the amount of reduction of head.

an ideal centrifugal pump, the head obtainable with a velocity V of e water at the periphery of the paddles should be $2h = H = \frac{V^2}{32}$. In actice, again this result is not obtainable, but results of $H = 0.86\frac{V^2}{32}$

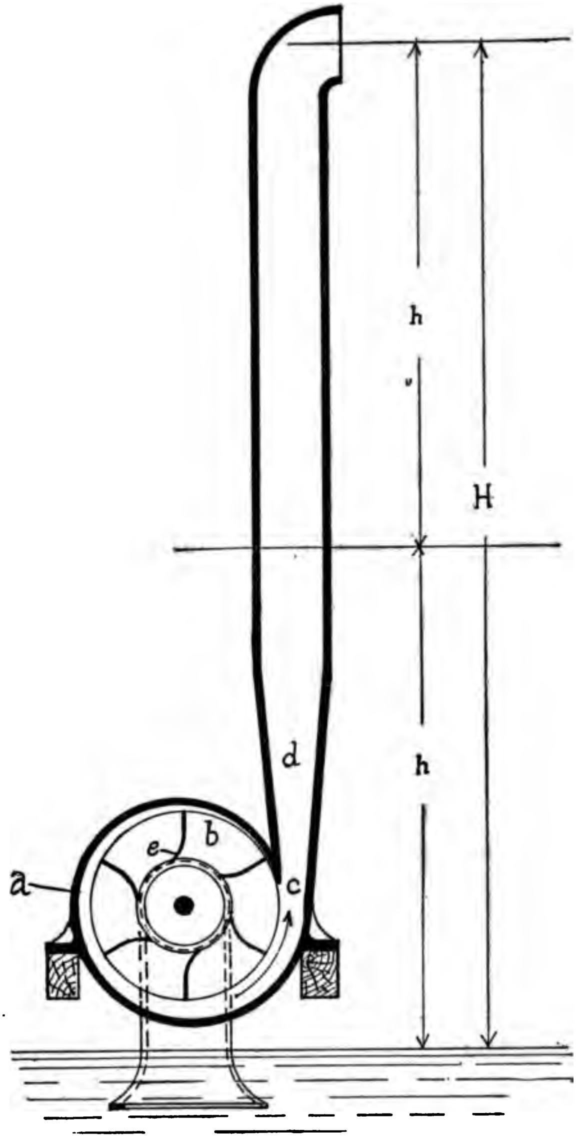


FIG. 166.

ve been obtained. It is to be remembered, however, that this height is not reached when there is no discharge, because then the energy of w does not exist at c, and cannot develop into additional pressure.

6.2.04. The advantages of utilizing to a greater extent the energy of

motion are: first, that more of the work which is spent in imparting to each pound of water that passes through the pump, both centrifugal pressure and an acceleration from rest to the velocity V, is utilized and not allowed to go to waste; second, that water can be raised to a given height H with a less peripheral velocity V of the paddles, which means

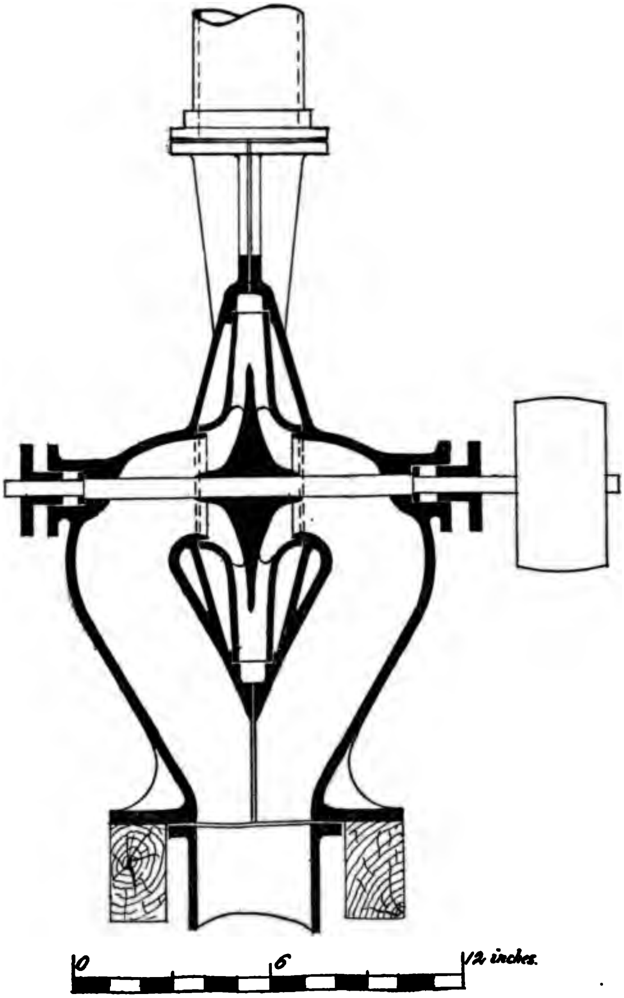


FIG. 167.

less frictional resistance in the pump, and often more convenient connection to motors. The reduced velocity will appear from inversion of the formulæ for h and H.

For the usual imperfect pumps $V=8\sqrt{h}$ theoretically.*

For a properly constructed pump $v=5.66\sqrt{h}$ theoretically,* the

*Really, if the velocity u in the discharge-pipe is considered, $V=\sqrt{64h+u^2}$ and $v=\sqrt{32h+\frac{u^2}{2}}$

reduction in velocity being nearly 30%. In practice, formulæ for the first case usually make $V=10\sqrt{h}$ or $11\sqrt{h}$, while the writer has obtained results with properly constructed pumps of $v=7\sqrt{h}$ and even $6.5\sqrt{h}$.

6.2.05 Another feature ordinarily met with in centrifugal pumps is the excessive backward curvature of the paddles, which causes an unnecessary increase in the velocity required to pump against a given head, thereby increasing fluid friction and helping to account for such relations as $V=11\sqrt{h}$. Radial blades give a lower value of V or v, but their inner ends should be curved forward, as at e, Fig. 166, so as to scoop up the water with a minimum of shock. The inlet velocity of water to a centrifugal pump should not, if possible, be much over 3′ per second.

6.2.06. Where the least amount of fluid friction is desirable in a pump, the runner should be kept small in diameter. A large diameter of paddles or impellers is oftentimes required in order to keep down the number of revolutions to such a limit that the pump can be directly coupled to an engine. For driving by an electric motor the more advantageous small runner is better adapted, as the speed of such motors is usually high. The friction will be less in the case of paddles shrouded at the sides, as in Fig. 167, than where they are open at the side, as in Fig. 164. The open blades, however, permit less leakage past their sides into the suction-pipe than the shrouded blades, as the zone of action of the latter is cut off by the shrouding, while that of the open ones extends by fluid friction somewhat beyond their edges.

6.2.07. If a centrifugal pump is properly constructed so as to utilize that part of the energy imparted to the mass of water as motion, it must nevertheless generally be so arranged with reference to its driving power that it can be run at a somewhat higher speed for a very short time, in order to start the flow in the discharge-pipe necessary afterwards to keep up the extra gain in lift. This increase of speed in starting can be avoided by providing an outlet in the discharge-pipe at one half of the total elevation to which the water is to be pumped, the outlet being opened on starting, so that the water can acquire its speed in the flaring pipe, after which it is closed again, whereupon the water will rise and flow out at the top of the pipe.

6.2.08. Unless centrifugal pumps are submerged, they will not prime themselves like a reciprocating pump with valves, because, in pumping out the air contained in them, they act simply as a fan-blower operating at the lower speed of a centrifugal pump, and are, therefore, capable of raising the water in the suction-pipe only to an insignificant amount. Centrifugal pumps are, therefore, generally provided with means for filling them with water, a foot-valve being generally provided at the lower end of the suction-pipe, in order to prevent its escape until the pump has attained its working condition. The means for filling the pump may be a small hand pump, an ejector, or a pipe from a reservoir into which the pump delivers its waters.

6.2.09. Centrifugal pumps are made in a great variety of forms. Some have single inlets, like the pump in Fig. 164. Others have inlets at each side, by which construction the inlets, and also the diameter of the paddles, may be kept down to a smaller size for the same capacity. Fig. 167, before referred to, illustrates a pump with double inlet, designed by the writer. It exhibits also the features for utilizing the energy of fluid motion before referred to and illustrated in Fig. 166. The flaring discharge and radial paddles contributed to the result

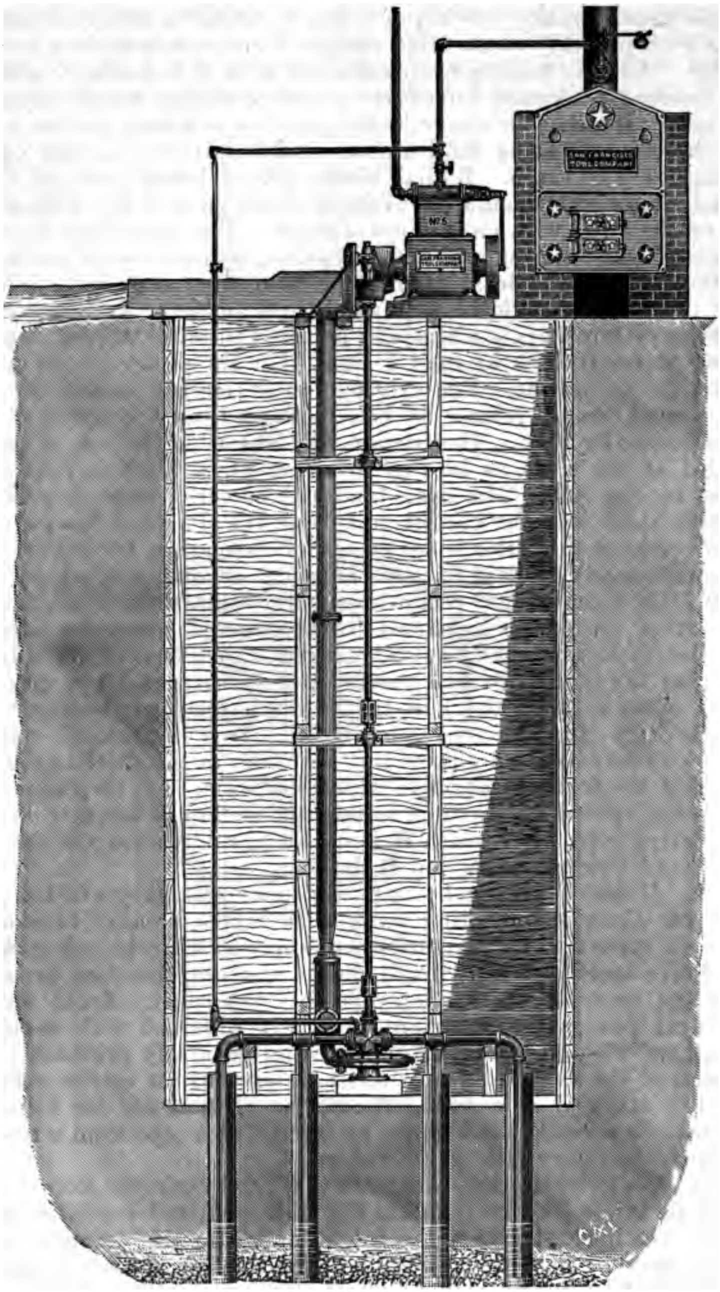


FIG. 168.

ated, which was a considerable reduction of the number of ions below that of the usual forms, like Figs. 164 and 165, ıble in the market. The double-inlet pumps have the advan- n comparison with the ordinary single-inlet, that the lateral e against the disk supporting the paddles is balanced. In the ds single-inlet pump the disk is perforated, as at *N*, Fig. 164, to he pressures on both sides to equalize to a certain extent.

). Pumps designed to raise water from wells are frequently ɔd with a vertical axis, like Fig. 168, extending to the surface, he power is applied most conveniently.

1. Usually centrifugal pumps are only required for low lifts, 0′ to 20′. They are, however, capable of working tly against heads of 100′ and over. For such however, the aim should be to utilize the energy of so as to keep the speed and the friction-losses s low as possible. Heads of 150′ have been over- y compounding the ordinary centrifugal pumps. ıould always be taken in compounding to convert excess of energy of motion acquired by the water first pump, into pressure before it is led into the f the second pump with the proper low velocity. 9 illustrates the proper principle of compounding ıgal pumps. The same result is obtained by rais- water to half the total height by the first pump,

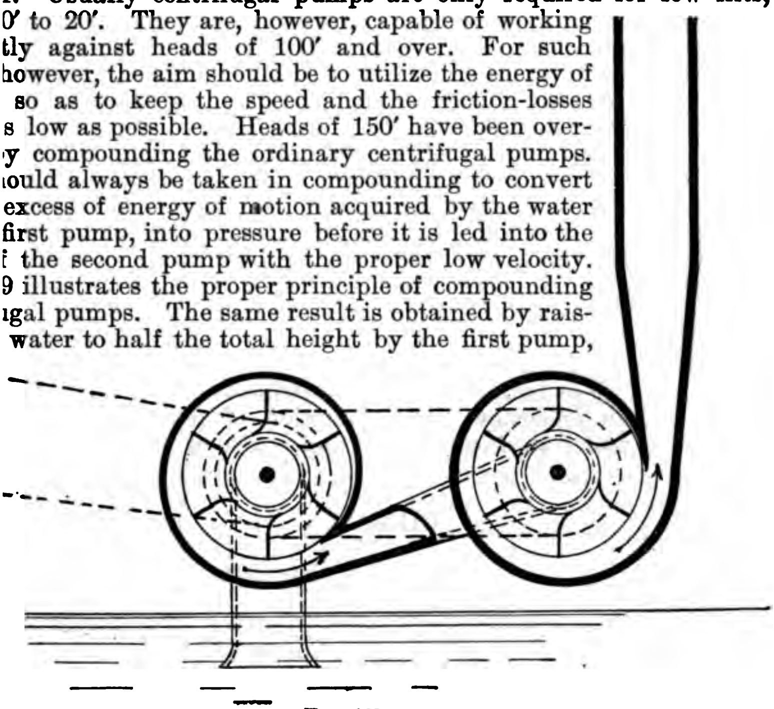


FIG. 169.

ɔn picking it up and raising it the remaining half by the second In many cases, however, the transmission of power to two sepa- ɔumps would be inconvenient. It is the same thing if the water ered to the second pump under a pressure equivalent to the ıat it would be lifted by the first pump, if the second pump did k it up before it was actually lifted.

2. The capacity of a centrifugal pump is proportional to the ıt which it runs. It therefore also increases with the lift. To e the discharge for a given head means loss of efficiency, because ed of the pump and that of the water issuing from the pipe are ed unnecessarily. Reduction of capacity by choking off is also ɔd with loss by fluid friction, and besides cannot be carried very hout stopping the discharge altogether. This quality of centrif- umps makes them less adapted for the ordinary purposes of

mining. They are suited for cases where a large quantity of water has to be got rid of in a short time, while the capacity is kept uniform until the supply is exhausted. A variable quantity of water can only be handled with best mechanical efficiency by providing reservoirs, which are alternately filled and then drained by the pump. In mines the smaller sizes only would find application, chiefly in drift mines and open workings, or perhaps in levels of mines operated through shafts.

6.2.13. Centrifugal pumps may be driven by steam or compressed-air engines, gas engines, electric motors, or waterwheels. Horse-powers are also sometimes used for very low lifts. The driving power is either directly coupled to the pump axis, or it is transmitted to a pulley on the axis by means of belting. Where they are driven by horses the average speed should be maintained considerably above the amount required to raise the water, because the horses will not keep up a uniform speed, and will frequently slow down, so that the discharge of the pumps will cease altogether.

6.2.14. The fact that centrifugal pumps do not admit of a wide range of variation of their capacity requires that a great number of patterns should be kept on hand by the manufacturers. For this reason the design and construction of the pump should be as simple and inexpensive as is compatible with the other features to be attained. Where efficiency is desired, it is generally necessary to design a centrifugal pump just to suit the conditions under which it is to operate.

6.2.15. Centrifugal pumps intended for raising coarse gravel, mud, etc., like in dredging, should be designed with a view of adaptation to the material to be handled, wearing qualities, and safety against breakdowns. High efficiency in consumption of power is generally not obtainable under these conditions, and is also of secondary importance here.

CHAPTER III.

Jet-Lifters; Ejectors.

6.3.01. These machines are operated either by steam or a head of water. Compressed air might also find application instead of steam, but no special apparatus for lifting water by means of its jet action can be obtained in the market. The common steam-ejectors could be thus used; with what efficiency, is not known to the writer. It is, however, probable that the efficiency will be extremely low.

6.3.02. Steam-ejectors or water-lifters are simple and cheap devices. Notwithstanding their low efficiency they can be made useful where efficiency does not cut much of a figure, where the work is only temporary, or where the time necessary for installation of apparatus is limited, and the suitable operating power is ready at hand for application. An advantage of machines of this class is also that they occupy little space, and are very light.

6.3.03. Steam-ejectors, if used in the bottom of a shaft or pit, should not be connected to the steam-supply by steam-hose, as the latter is liable to give out at any time. When it is desirable to have the ejector arranged so that it can be conveniently and rapidly let down as the work of sinking progresses, it is necessary to put in a telescope-pipe like those described for direct-acting sinking-pumps in 3.2.08. There

ld be a stop-valve close to the ejector, to control its operation, and lose to the boiler, so that the steam-pipe can be repaired or extended the machine is to be lowered There should also be a check-valve e suction-pipe, so that there is no possibility of steam being blown through the suction when the sump has been drained. Steam-

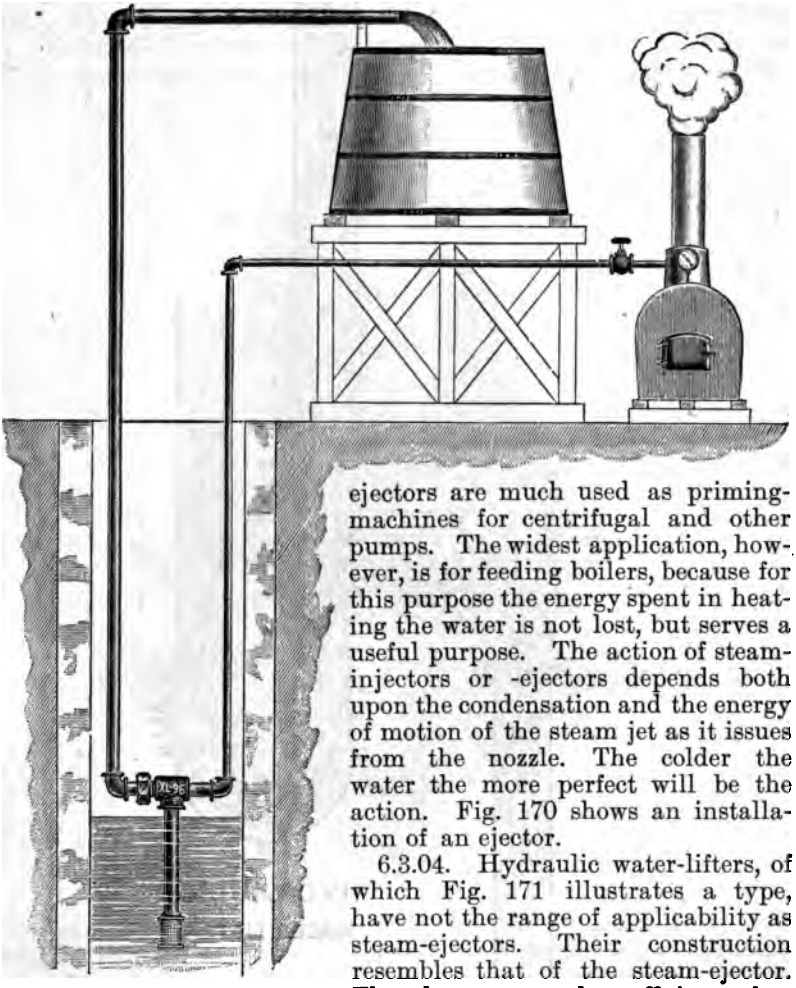


FIG. 170.

ejectors are much used as priming-machines for centrifugal and other pumps. The widest application, however, is for feeding boilers, because for this purpose the energy spent in heating the water is not lost, but serves a useful purpose. The action of steam-injectors or -ejectors depends both upon the condensation and the energy of motion of the steam jet as it issues from the nozzle. The colder the water the more perfect will be the action. Fig. 170 shows an installation of an ejector.

6.3.04. Hydraulic water-lifters, of which Fig. 171 illustrates a type, have not the range of applicability as steam-ejectors. Their construction resembles that of the steam-ejector. They have a very low efficiency, but could find application for drainage poses under the conditions mentioned in 6.3.02. Where heat is ctionable, as in the bottom of a shaft, and where water-power is at osal, they would be preferable to steam-ejectors. Where the lift is the required driving-head will be correspondingly so. Unless there very heavy head, hose may be used for connection to the supply-s, thereby affording a more flexible connection than telescope-pipes, h may be an advantage in many cases.

3.05. Gritty water soon wears out ordinary ejectors. The nozzles ld therefore be made of very hard material where such water is to

be lifted by them. Very acid water has the same effect, for which ı ejectors for corrosive liquids are made with hard lead linings, wit celain nozzles, or entirely of porcelain.

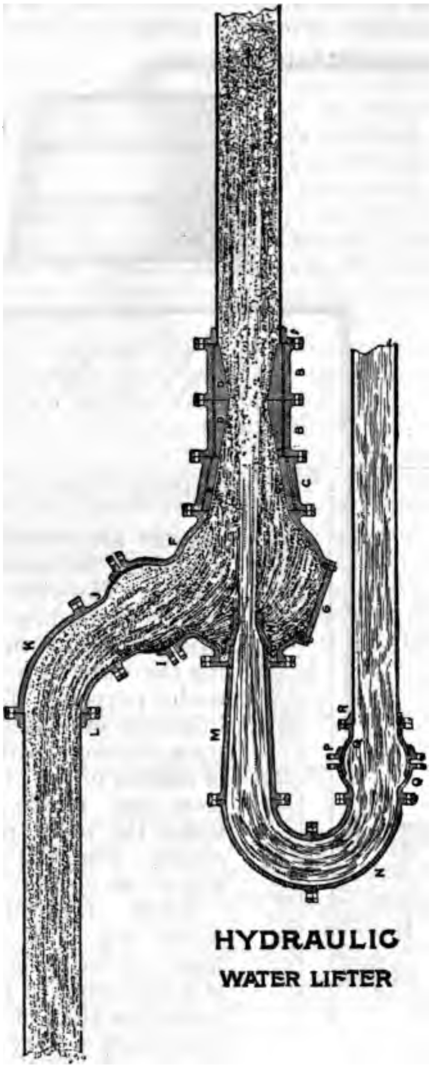


Fig. 171.

CHAPTER IV.

Pulsometers.

6.4.01. The invention of C. H. Hall, the pulsometer, is one (most useful pieces of apparatus for raising sandy or acid water to h not exceeding 100′, where economy of fuel is less important than (

ness of installation, and freedom from risk of breakdowns. When used for sinking operations in shafts, the steam- and water-pipes must be arranged the same as for other sinking apparatus with telescope connections, so that the machine can be lowered quickly or hoisted out of the way when blasting.

6.4.02. By reference to Figs. 172 and 173, it will be seen that to the tapering necks of chambers *A A* there is attached, by means of a flange joint *B*, a continuous passage from each chamber, leading to one com-

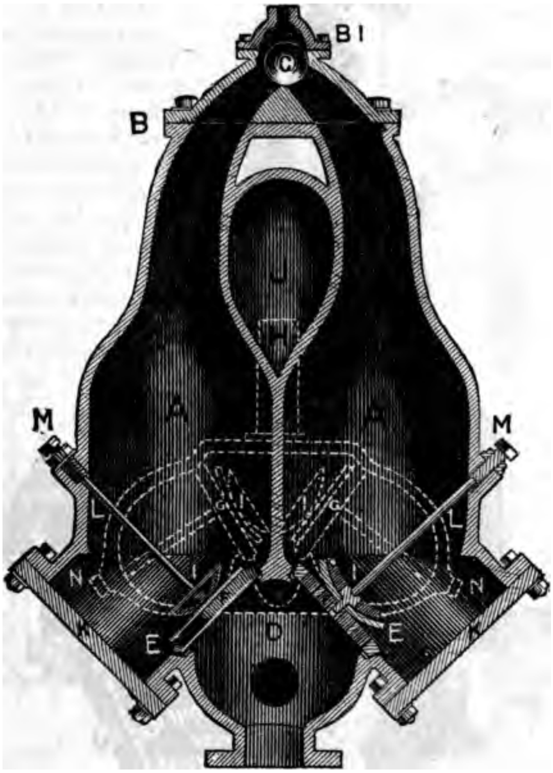


FIG. 172.

mon upright passage, into which a small ball *C* is fitted so as to oscillate with a slight rolling motion between seats formed in the junction. The chambers *A A* also connect by means of openings with the vertical induction passage *D*, which openings are fitted with the valves *E E* and their seats *F F*.

6.4.03. The delivery passage *H* communicates with each chamber through openings fitted with the valves and valve-seats *G G*, of the same style as in the induction passage. *I I* are valve-guards. The vacuum-chamber *J* between the necks of chambers *A A* connects only with the induction passage below the valves *E E*. *K K* are doors covering the openings, affording access to the valves and seats when necessary. Vent plugs are inserted into these flanges for the purpose of drawing off the water to prevent freezing. *L L* are struts by which the suction seats, valves, and guards are tightly pressed into place. *N N*

are bolts by which the discharge seats, valves, and guards are held in place. A small air check-valve is screwed into the neck of each chamber A A, and one into the vacuum-chamber J, so that their stems hang downward. The check-valve in the neck of each chamber A A allows a small quantity of air to enter above the water, to prevent the steam from agitating it on its first entrance, and thus forms an air-piston, tending to

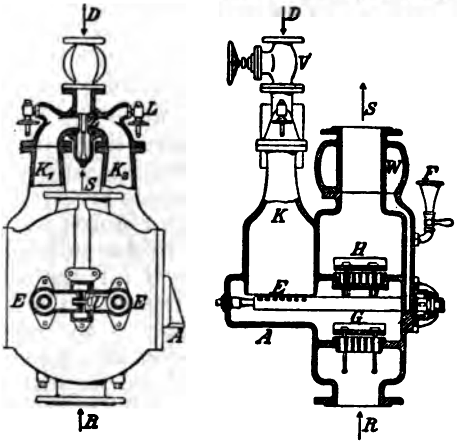
FIG. 173.

prevent condensation. The check-valve in the vacuum-chamber J also admits sufficient air to cushion the ramming action of the water consequent upon the alternate filling of each chamber.

6.4.04. The two working-chambers fill and discharge alternately, like in a steam pump. The steam enters at the top, or neck, and passes into whichever chamber is uncovered by the steam ball-valve, and pressing upon the surface of the water forces it down and out through the discharge-valves, and into the discharge-pipe. As soon as the water-line has been forced downward to the discharge outlet, the steam above it instantly condenses, a partial vacuum is formed, and the chamber in

ןuence suddenly fills again. Now, while the steam was entering ıamber, which we will designate as the "left-hand" one, the steam alve was seated over the entrance to the "right-hand" chamber, ıting the entrance ım thereto; but as as the sudden col- of steam occurs, alve is instantly ı over to its other ,t the entrance to left-hand" cham- This cuts off the ssion of steam o, and allows it to the other cham- ıd expel the water rom in the same manner as described for left-hand" chamber. Steam and water y the same chamber successively, and will alternate, keeping up a continuous outflow ıg as steam and water are supplied.

05. Priming is performed by pouring water



·am inlet
valve.
·rating tongue
-valve.
·tion-pipe
·mn-pipe.
charge valve.

G Suction-valve
K_1 K_2 Working-chambers
E E Injection-pipe.
U " regulator
W Air chamber
F Priming-funnel
A Bracket-feet

FIG. 175.

FIG. 174.

gh the plugged opening in the middle chamber, or through the ed opening on the discharge outlet side. Care should be taken to ɔe the plug quickly after priming. Fig. 174 shows a pulsometer ıce to pump out a shaft or well.

6.4.06. While the pulsometer is capable of lifting water 100′, most general application is for lower lifts of 25′ to 50′. The ste pressure naturally has to be increased with the increase of the forc part of the lift.

6.4.07. Where the water has to be kept down close in order to ena the men to work in the bottom of the shaft, two pulsometers can used, one of which will operate while the lengthening of the pipe the other is proceeded with.

6.4.08. Pulsometers are made in sizes to meet any capacity, the tab of the chief makers running up to 2,000 gals. per minute. The ste consumption is high. Experiments made in Germany show consun tion of 200 lbs. and over of steam per horse-power of water lifted per ho

6.4.09. Pulsometers should be improved, if possible, by prevent condensation of the steam during its entrance into the working-chamb It should, after filling a chamber, be condensed rapidly by some fo of spray-injection like that used in the Korting pulsometer shown Fig. 175. The steam should again be prevented from condensing dur the forcing pulsation. By reducing these two condensation losses t minimum, Korting claims to have obtained results of less than 100 l of steam per water horse-power per hour, which is a better result th obtained with ordinary steam pumps.

CHAPTER V.

Air-Lift Pumps.

6.5.01. The operation of this apparatus depends upon the buoyar of air introduced into the column-pipe in bodies alternating with liqu the air forming virtually a piston, more or less complete, and pushi the water ahead of it. Fig. 176 illustrates the principle involved. T column-pipe is an open pipe, the lower part of which requires to be su merged for such a depth that the hydraulic pressure due to immersi will not quite equal the pressure of the compressed air entering t bottom of the column-pipe by means of the small air-pipe. The less t lift H compared with the submersion h, the greater is the efficier obtained. This is also greatest when the air pressure exceeds l slightly the pressure due to hydraulic submersion of the air outlet.

6.5.02. The air-lift pump just described is said to have been inven in the last century at Freiberg, Saxony. One of the Siemens broth made experiments with it more recently. Later still, in 1889, Mr. R E. Browne, in conjunction with the writer, made a series of experime on this apparatus, which had been again invented and patented Dr. J. G. Pohlé. As there has been considerable inquiry concerni this pump, the writer reproduces a paper prepared and read before t Technical Society of the Pacific Coast by Mr. Browne, giving an accou of the experiments and the results obtained.

Dr. Pohlé's Air-Lift Pump.

By Ross E. Browne and H. C. Behr, Members Technical Society.

[Read February 14, 1890.]

During the month of August last, the writers, jointly with Mr. P. Randall, conducted a series of tests with Dr. J. G. Pohlé's air-lift pum ing apparatus.

Figs. 176 and 177 will show the simplicity of the pump.

A good efficiency being found, and the apparatus having, for many purposes, very apparent advantages over the forms of pump in common use, it is thought that a record of the tests may be of interest.

The pump-column is an open pipe partly submerged in the water to be pumped. A small pipe leading from an air-receiver to the foot of and a short distance into the pump-column, delivers compressed air, which forms in piston-like layers, and rising rapidly in the column, does the work of pumping. The water is discharged in alternate layers with the air.

The apparatus tested was erected without due regard to best dimensions, and we deem it proper to state that the efficiencies found could have been increased by a few simple alterations. Pipes of different diameters were not provided, and we were able to change only the length of the pump-column, the amounts of submersion and lift, and the pressure in the receiver, hence the quantity of air supplied.

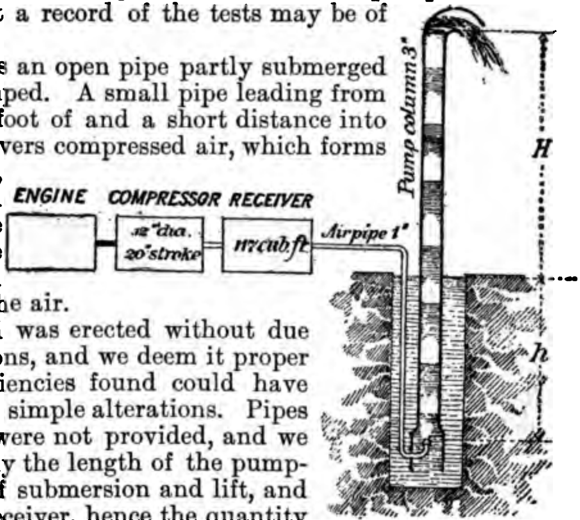


FIG. 176.

The diameter of the pump-column was 3″, of the air-pipe 0.9″, and of the air-discharge nozzle ⅝″. The air-pipe had four sharp bends and a length of 35′ plus the extent of the submersion.

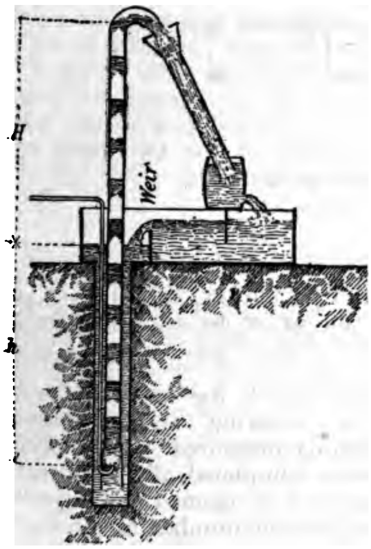


FIG. 177.

The water was pumped from a closed pipe well (55′ deep and 10″ in diameter), and was discharged into a tank and delivered—over a quadrantal weir—back to the well.

A long mercurial column was connected with the receiver for the purpose of obtaining accurate measurement of pressure.

The quantity of air delivered to the pump was obtained by two methods, as follows:

First Method.—The cubic contents of the receiver were measured. The escape-cocks from the receiver were closed and the compressor was started. Beginning with atmospheric pressure, the increase of pressure was noted for each thirty strokes of the compressor-piston, until a pressure was reached beyond that required in the pump tests. The contents of the receiver were 117 cu. ft.

The following are the results of two separate tests:

The compressor made uniformly one stroke per second. The atmospheric pressure was 2.51′ of mercury. The air was unusually dry.

TABLE I.

No. of Strokes of Compressor-Piston.	Temperatures.				Pressures in Receiver Above Atmosphere. Feet of Mercury.	
	Receiver.		Atmosphere.			
	Test No. 1.	Test No. 2.	Test No. 1.	Test No. 2.	Test No. 1.	Test No. 2.
0	78° F.	80° F.	75° F.	77° F.	0	0.01
30	....	....	....	....	(0.76)?	0.94
60	....	....	....	....	1.72	1.77
90	....	....	....	....	2.48	2.56
120	....	....	....	....	3.24	3.31
150	....	....	....	....	3.95	4.08
180	....	....	....	....	4.67	4.81
210	....	....	....	....	5.34	5.54
240	....	....	....	....	6.00	6.29
270	86°	88°	75°	77°	6.66	7.00

These data formed the basis for calculating the number of pounds of air delivered per piston stroke of the compressor, to the receiver at any

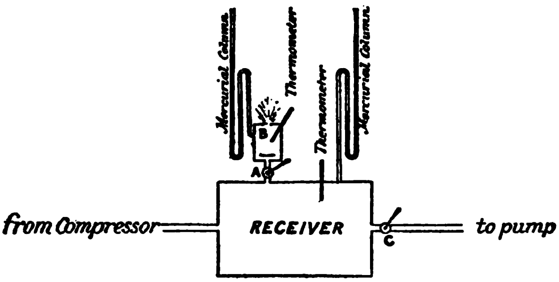


FIG. 178.

required pressure. An average of the results of the two tests was adopted. The following table gives the values obtained:

TABLE II.

Pressure in receiver above atmosphere. Lbs. per square inch.	0	5	10	15	20	25	30	35	40
Lbs. of air delivered per stroke of compressor	.104	.098	.093	.088	.083	.081	.079	.077	.076

Second Method.—A small auxiliary chamber *B* was attached to the receiver. (See Fig. 178.) Compressed air entering this chamber escaped into the atmosphere through a carefully measured circular orifice in thin plate. After a pump test had been completed, the compressor was kept running, cock *C* was closed, and cock *A* opened and adjusted until the conditions in the pump test, regarding number of strokes of compressor per minute and the pressure in the receiver, were repeated and maintained.

The pressures and temperatures of the compressed air in chamber *B* and of the atmosphere, furnished the data upon which to base a calculation of the quantity of air escaping through the circular orifice.

This quantity was evidently the same as that supplied in the pump test. Such tests were made from time to time, and served to check the values taken from Table II. A few of these are given below. Diameter of orifice was 0.391″. Atmospheric pressure, 14.7 lbs. per square inch. Weisbach's and Zeuner's coefficients of efflux were used.

TABLE III.

No. of Pump Test.	No. of Strokes of Compressor per Minute.	Pressures above Atmosphere, lbs. per sq. in.		Temperature Fahr.			Lbs. of Air Delivered per Second.	
		Receiver.	Chamber B.	Receiver.	Chamber B.	Atmosphere.	Table II.	Orifice Test.
1	60	31.1	20.2	77°	77°	68°	.078	.075
5	60	30.6	20.3	74	73	73	.078	.075
10	60	24.1	21.7	78	75	74	.081	.077

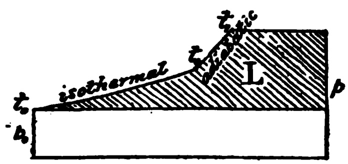


FIG. 179.

The engine used to drive the compressor was built for ten times the power actually applied to the compressor, hence a test of the efficiency of the entire plant was not made.

Table IV gives the results of the pump tests. The "efficiency of the pump" is based upon the least work L theoretically required to compress the air and deliver it to the receiver. (See Fig. 179.)

Atmospheric conditions $= p_0, t_0$.
Receiver conditions $= p_1, t_1$.

The values given in the table take no cognizance of the losses of power in the engine and compressor.

If we assume the efficiency of a suitable compressor to be 70%, the efficiency of the pump and compressor together would be 70% of that given in the table for the pump alone.

TABLE IV.

No. of Test.	No. of Strokes of Compressor per minute.	Pressure in Receiver above Atmosphere, lbs. per sq. in.	Temperatures Fahr.			Water Lift "H," in feet.	Submersion "h," in feet.	Pressure corresponding to "h," lbs. per sq. in.	Weight of Air Supplied, lbs. per sec.	Water Pumped, cub. ft. per sec.	Work of Isotherm Compression L, ft. lbs. per sec.	Work of Water-Lift W, ft. lbs. per sec.	Ratio $\frac{H}{h}$	Efficiency of Pump $\frac{W}{L}$ in per ct.
			Receiver	Atmosphere	Water									
1	60	31.1	77	68	68	75.2	53.0	23.0	.078	.1755	2408	824	1.4	34
2	60	30.8	77	72	68	75.4	52.8	22.9	.078	.1799	2445	846	"	34
3	45	27.6	78	71	68	75.3	52.9	22.9	.059	.1488	1716	700	"	41
4	31	25.4	77	74	68	75.3	52.9	22.9	.041	.0757	1156	356	"	31
5	60	30.6	75	72	67	35.1	53.2	23.1	.078	.3136	2459	687	0.6	28
6	46	26.8	78	74	67	35.2	53.1	23.0	.061	.3014	1770	662	"	37
7	30	24.9	78	76	67	35.0	53.3	23.1	.041	.2425	1150	530	"	46
8	22	24.0	78	72	67	35.0	53.3	23.1	.030	.1941	802	424	"	53
9	60	23.8	78	72	70	54.7	33.6	14.6	.081	.1538	2151	525	1.6	24
10	34	17.4	77	72	69	54.7	33.6	14.6	.049	.0824	1056	281	"	27
11	23	16.1	76	73	69	54.5	33.8	14.6	.033	.0576	681	196	"	29
12	60	18.8	76	71	69	69.9	18.4	10.0	.084	.0338	1904	147	3.8	8
13	33	11.9	76	75	69	69.6	18.7	10.0	.050	.0067	837	29	"	3
14	60	20.6	80	77	69	62.1	26.2	11.4	.083	.0931	2041	361	2.4	18
15	38	15.2	80	74	70	62.4	25.9	11.2	.056	.0663	1090	258	"	24
16	19	12.3	79	75	71	62.4	25.9	11.2	.029	.0185	489	72	"	15
17	60	18.9	79	74	67	31.5	20.1	8.7	.084	.1488	1922	292	1.6	15
18	34	12.3	78	72	68	31.5	20.1	8.7	.052	.1126	860	221	"	26
19	20	10.0	76	70	68	31.3	20.3	8.8	.031	.0633	432	124	"	29
20	60	20.3	69	68	67	26.3	25.3	11 0	.083	.2296	2013	377	1.0	19
21	41	15.8	70	66	67	26.3	25.3	11.0	.059	.2050	1178	336	"	29
22	22	12.5	70	67	67	26.3	25.3	11.0	.033	.1420	558	233	"	42
23	60	21.9	72	67	69	20.3	31.3	13.6	.082	.2954	2050	374	0.7	18
24	27	15.1	72	67	69	20.3	31.3	13 6	.040	.2398	769	304	"	39
25	22	14.4	72	67	69	20.3	31.3	13.6	.032	.2086	594	264	"	44
26	60	23.1	74	67	69	15.3	36.3	15 7	.082	.3540	2105	338	0.4	16
27	30	17.4	73	68	69	15.3	36.3	15.7	.043	.3182	918	304	"	33
28	19	16.2	73	69	69	15.3	36.3	15.7	.028	.2558	572	244	"	43
29	60	17.1	74	69	69	36.0	15.6	6.8	.086	.0693	1818	156	2.3	9
30	34	10.1	73	70	70	36.0	15.6	6.8	.052	.0424	749	95	"	13
31	18	7.4	73	70	70	36.0	15.6	6.8	.029	.0093	323	21	"	7
32	60	15.8	76	72	70	41.0	10.6	4.6	.087	.0146	1757	37	3.9	2
33	22	7.1	74	72	70	41.0	10.6	4.6	.035	0	382	0	"	0

An inspection of the above table shows:

First—That, for a given submersion h and lift H, the best efficiency was obtained when the pressure in the receiver did not greatly exceed the pressure due to the submersion.*

Second—That the smaller the ratio $\frac{H}{h}$, the better was the efficiency.

*NOTE.—This was only true when the ratio $\frac{H}{h}$ was kept within reasonable limits—i. e. where H was not much greater than h.

We may say in a general way that under the better adapted pressures in the receiver, the pump, as erected, showed the following efficiencies:

For $\frac{H}{h}=0.5$	50%
" " 1.0	40
" " 1.5	30
" " 2.0	25

It is apparent that the air-pipe should not have been reduced at the discharge end, as such reduction necessitated a greater pressure in the receiver for the delivery of the air to the pump.

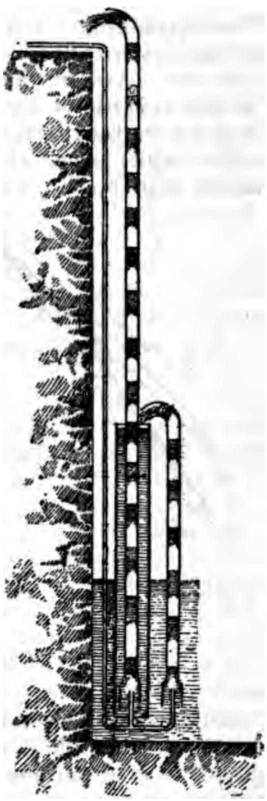


Fig. 180.

Unfortunately, the data is wanting for a reliable estimate of the loss due to the frictional resistance in the small air-pipe. A rough estimate shows that such loss must have been large. The substitution of a $1\frac{1}{2}''$ air-pipe in place of the $1''$ would have appreciably augmented the efficiencies given in the table. In justice to the pump, a considerable allowance should be made for this easily avoidable loss.

The last test (No. 33) shows a limit of lift for a given submersion, beyond which a large excess of pressure is required to pump even an insignificant quantity of water.

For good efficiency, it becomes necessary that the lift should not be very great as compared with the submersion.

Where a shallow sump only is available to pump from, and a considerable lift is to be made, Dr. Pohlé introduces an auxiliary pipe to receive the water, after being pumped to a small height, and act as pump-well for a higher lift. (See Fig. 180.)

We have not attempted an analytic treatment of the action of this pump. Such treatment would have little value without coefficients, derived from a more comprehensive set of tests.

The simplicity of this pump commends it for many uses.

Among the numerous applications which Dr. Pohlé proposes for this air-lift may be mentioned: the drainage of mines; the supply of water from deep wells; the lifting of liquids which damage the working parts of the pumps ordinarily used; the increase of the lift and capacity of other pumps by introducing an air-jet into the pump-column.

6.5.03. Although the air-lift pump can, under certain conditions, be made a comparatively efficient machine, particularly if the compressing-plant is such, its application to mine drainage is generally inconvenient, and its use for such purposes will certainly never be extensive. It can, however, be made a useful auxiliary to a sinking-pump, where a flooded mine, affording a chance for the necessary submersion, is to be pumped out, and where air-compressing machinery is at hand. Special provisions of air-compressing plant for operating the air-lift pump would hardly pay. The capacity of air-lift pumps cannot be varied in very wide limits, without greatly reducing the efficiency.

6.5.04. Compressed air is also sometimes introduced into the column-pipe of a pump, in order to increase the lift beyond that otherwise admissible on the pump. This is probably the most useful application of the air-lift pump in mine drainage. To start such an apparatus the air pressure must be sufficient in the beginning to balance the column full of water; it can then be reduced to that necessary to support the mixed column of water and air when the flow has been started. A better plan is, though, to drain the column-pipe to such a level that the air pressure will overbalance the hydrostatic head and start the flow. The application of air-lift pump just described is very conveniently made, as it requires no special submersion column.

6.5.05. Air-lift pumps must be placed in vertical shafts. No data on the working of inclined air-lift pumps are known to the writer. It may be doubted if they would work at all if the inclination were made appreciable, as the air bubbles would hug the high side of the pipe and afford more chance for back-flow of water on the lower side.

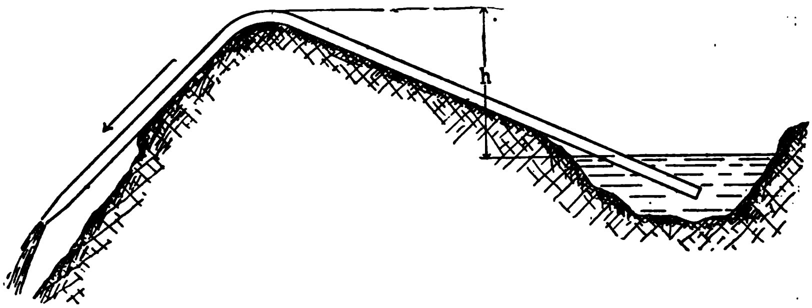


FIG. 181.

CHAPTER VI.

Siphons.

6.6.01. Though not a water-*raising* appliance in the proper sense of the term, since the water by this apparatus can only be lifted or transported over an eminence limited in height and discharged on the other side of it at a level lower than that of the supply, siphons can find application in many instances for forming a water communication over an elevation between two distant points; also, for draining levels or open workings, thereby doing away with the necessity of installing a pump.

6.6.02. In construction, the siphon is a very simple piece of apparatus, but the conditions that govern its working are many, and it is therefore proper to consider the principles involved, and the means employed in securing or aiding its proper action.

6.6.03. A siphon consists essentially of a pipe curved downward at each end, as shown in Fig. 181, with one end dipping into the supply-reservoir, and the other discharging at a level lower than that of the supply.

6.6.04. The height h, over which a siphon may automatically transport a liquid, depends, firstly, upon the specific gravity of the liquid to

be lifted. Thus, for example, a heavy liquid like quicksilver cannot be raised by a siphon over the same height as water, and water containing heavy substances in solution or suspension cannot be raised over the same height as pure water. Secondly, it depends upon the barometric pressure, the possible lift being therefore less at high altitudes than at sea-level, and varying also with the state of the weather. In designing a siphon which is to operate at all times, it is therefore necessary to base the calculations upon the lowest observed barometric pressure. The working of a siphon depends also very materially upon the temperature of the liquid. If this temperature be higher than that of the boiling-point which the liquid has at the low absolute pressure existing at the highest part of the siphon, the liquid will begin to boil at that point and give off vapor, which will fill the siphon and cause it to stop flowing. It is well, therefore, to shed-over the rising and high parts of long siphons, so that the heat of the sun will not raise the temperature of the liquid. A similar effect will be produced by air or other gases held in solution. Such gases are liberated when the pressure is reduced, and cause stoppage of flow in the same way as the vapors.

6.6.05. These conditions limit, as with all water-suction apparatus, the height of the column of the liquid which can be supported by the overpressure of the atmosphere. This height will be further reduced by an amount necessary to cause the required velocity of flow and to overcome the frictional resistance.

6.6.06. When a charged siphon is not in operation, the air accumulates at the highest point; but when there is a flow, the latter presses the bubble of air ahead so that it occupies a position ahead of the highest point, the position depending upon the energy of the current and the grade of the descending leg of the siphon.

6.6.07. The air and gases held in water are liberated even at a moderate reduction of pressure, and, as nearly all water is charged more or less with gases, these will be liberated in any siphon, and will cause thereby a gradual increase of pressure, a little beyond the highest point, which thereby gradually reduces the available flow-producing-head, so that the flow becomes less and less, and when the pressure equals the acceleration-head, ceases altogether. Long siphons will run less time in this manner than short ones, because, in the former, there is a greater volume of water containing air in the pipe, and more time and surface afforded for the liberation of gases in the longer passage of the water.

6.6.08. When the siphon is not too long, and when the acceleration-head is sufficient to give the water a considerable velocity, the air and gases may be entrained by the rapid current and carried out at the end of the discharge branch, if the latter is not too steep. In most cases, however, it is necessary to provide artificial means to remove the accumulated gases, either periodically or continuously. The means employed for this purpose is usually a hand air-pump connected with its suction to the highest point of the siphon. In order to collect the gases at one point, the siphon should have the shape shown by Fig. 182, where the descending branch falls more abruptly, in order to prevent entraining any of the air accumulated in the chamber *a*. The pump *b* may also serve to prime the siphon, if it has sufficient capacity. There should be no level pipe in the siphon, but it should ascend all the way toward the accumulator-chamber, which latter should present a large opening to the pipe, so that the air will readily find its way into it and not rush

past into the descending leg, where it might be retained by the force of the current. Where there is fall available for the water discharged from the siphon, it may be utilized to run a small waterwheel for driving, by means of suitable transmission, the air-pump at the highest point of the siphon, so as to continuously remove the air.

6.6.09. A siphon, arranged as in Fig. 181, should either have a reduced discharge opening or a regulating valve at the lower end, or

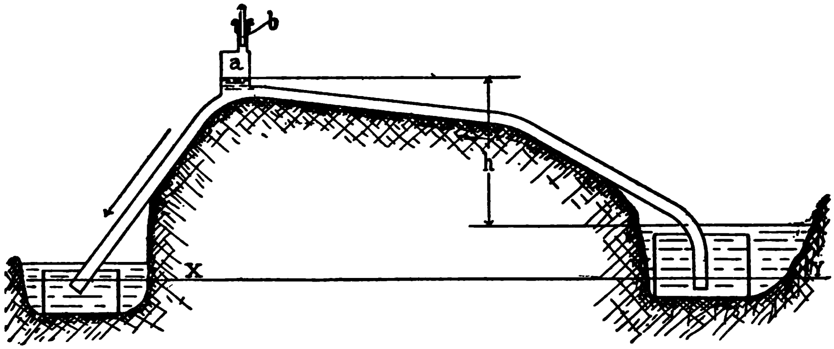


FIG. 182.

the descending leg should be smaller in size than the ascending one. If such precautions are not taken, the water may run out of the descending leg faster than it can flow into the ascending one, with the result that air will enter by way of the descending leg and stop the operation of the siphon. This result may be avoided in any siphon by always having both ends submerged, or by turning them upwards, as in Fig. 183. If a level line x y intersects the two upturned branches, the water

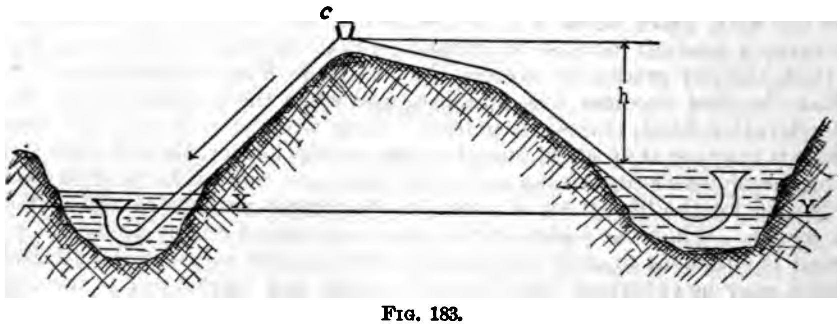


FIG. 183.

will not run out of the siphon, and air cannot enter it, when, from any cause, the supply level sinks below the top of the upturned entrance branch. This arrangement also secures the self-starting of the siphon thus stopped, when the supply level again rises above the edge of the branch. The submerged ends are advantageously made flaring or bell-mouthed, so that the water will be gradually accelerated as it enters the siphon, and will leave it with an easy flow. In this manner a few inches of lift or a somewhat increased flow may be gained.

6.6.10. There should be valves at each end of the siphon, which can be closed, when it becomes necessary to prime it, by filling it with

either through the plug-hole *c*, Fig. 183, at the
st point, or by means of the pump, Fig. 182.
11. It is important that siphons, particu-
long ones, should be absolutely tight, so that
: can enter them; otherwise, this also will
to be removed with that liberated from the

12. Advantage should be taken of the action
ions wherever possible, not merely by them-
, but generally more frequently to aid
ing-plants, the pipes from which, in order to
the point of discharge, have to pass over
ening elevations. The lower the total lift in
a case the greater will be the proportional
by properly arranging the siphon part of the
Occasionally, also, the reverse proceeding
e advisable, and a large siphon may be aided
talling low-lift pumping machinery.

CHAPTER VII.

r-Raising Appliances of Small Capacity Operated by Men or Animals.

01. These are more frequently for temporary
s in prospect work, or draining shallow holes
fts or in river channels. Much of this work
e by men and horses or mules, because its
and uncertain duration does not warrant
tlay for mechanical power apparatus.
02. The power of men can be applied in
s ways to pumping. It is generally by hand-
that the small water-raising machines used
r mines are operated. Hand-power may be
d in a reciprocating manner, or rotatively
ans of a crank.
03. Often the hand pumps are constructed
mine to suit the conditions required. Fig.
lustrates a hand pump of this kind. The
is an ordinary piece of gas-pipe or tubing.
oot-valve *a* is simply a piece of leather, or
rubber cut out of the sheet, as shown by the
, and clamped between two washers, so that
art *b* serves as a hinge. The seat *c* is made
rcular piece of sheet-iron with a central hole
what smaller than the valve. The valve, with
t and a lower gasket, is clamped between the
s for connecting the suction-pipe to the pump-
. An ordinary vertical check-valve may also
d instead of this construction. The bucket *d*
de of a piece of leather rolled together in a
l form, the smaller end being nailed to the

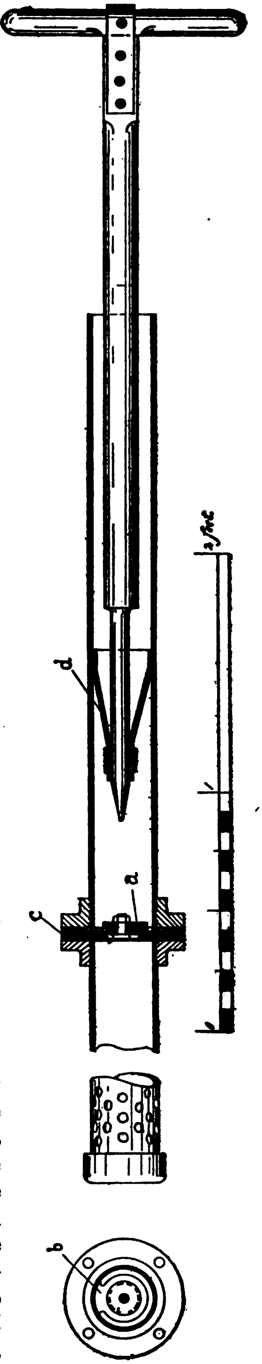


FIG. 184.

wooden pumprod, and further secured by marline or copper wire. The edges of the leather, where they overlap, are beveled so that they can slip past each other and allow the cone to collapse on the down-stroke, so that it can pass down through the water. On the working-stroke the cone again spreads out, and the upper edge is pressed against the side of the pump-barrel by the water, thus serving as valve and piston-packing at the same time. By making the cross-section of the rod equal to half the area of the pipe, the pump will be double-acting, and will discharge at each stroke half the amount of water which it draws in during the suction-stroke. Sometimes pumps of this kind are made with wooden barrels of square cross-section. The pump, Fig. 185, is only suitable for suction lift, but can handle a large amount of water.

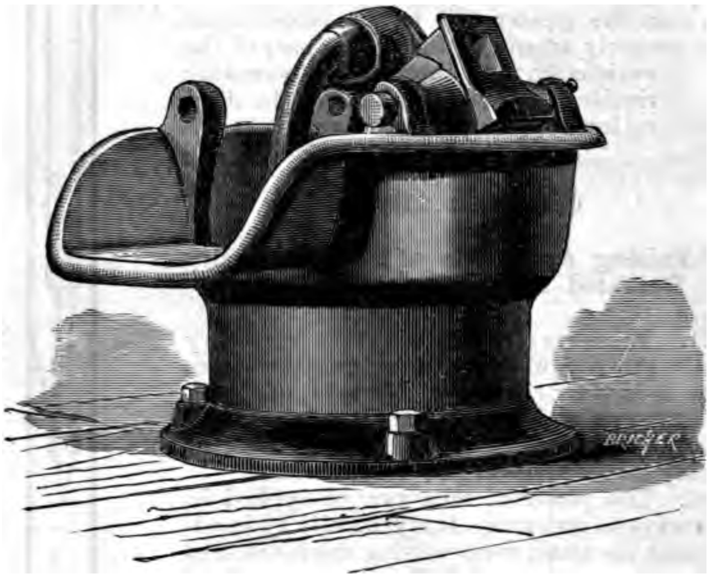


FIG. 185.

6.7.04. The work of men is most advantageously utilized in reciprocating motion of the hands; that is, men can do more and work longer than in any other manner, if they perform the work with a horizontal, rowing motion, at which they are seated, and can brace their feet.

6.7.05. In raising water, the work of men, when transmitted by a crank, can be applied either to bailing by means of a winch, or to operating pumps by secondary or driven cranks. Where there is one double-acting pump, or two single-acting pumps with opposite cranks, the crank-angle should be such with reference to the hand-crank that the greatest resistance will occur at such a point when the hand-crank is in the most favorable position to utilize the effort of the operator with the least fatigue to himself. Where there are a number of pumps with the cranks so disposed relatively that the resistance at the hand-crank will be almost uniform in the direction of rotation, a flywheel of sufficient weight should be mounted on the hand-crank shaft, in order to distribute the less fatiguing variable effort of the operation.

6.7.06. The crank can also be employed to operate a Chinese pump

water-elevator. The Chinese pump, Fig. 186, may be constructed in :ious ways. One of the most usual forms consists essentially of an lless canvas or rubber belt passing over two pulleys, one close to the .nt of discharge, and the other submerged in the water to be raised. the outside of the belt are fastened a series of blocks about 18" to 24" art. The upper pulley is rotated by means of a hand-crank, or by a .t on a pulley, if by animal or mechanical power. The ascending side the belt is encased in a rectangular wooden pipe, into which the ›cks on the belt fit as closely as possible without risk of jamming fast. .e blocks in ascending carry up the water between them, minus the ıkage, and push it out at the top of the wooden pipe. Similar pumps also made with chain belts instead of canvas or rubber, as in Fig. 187.

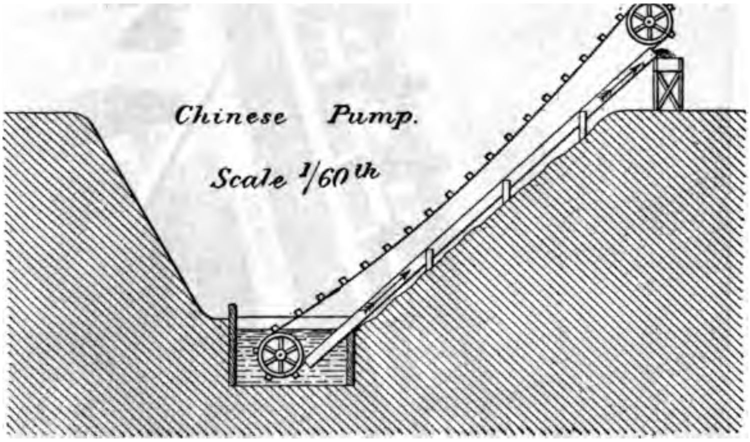


FIG. 186.

6.7.07. The work of horses, mules, and cattle in raising water is, like in ıost other employment of such animals, nearly always utilized in the ırm of traction. Occasionally they are found operating machines of the 'eadmill character, in which the animal raises its own weight, as when is walking up hill, except that the "hill" slips down as much as the ıimal raises itself, so that the latter remains in a fixed position, only oving its legs in a climbing motion and pushing back the surface ›neath it. Such apparatus, however, requires special training of the ıimals, and traction animals are therefore rarely used in that way for ıter-raising. Working animals trained for traction purposes can ways be readily obtained. For this reason, it is best to use such power ıchines for which the training of the animals already fits them.

6.7.08. Animals may exert tractive force either in a straight or in a 'cular path. In the former they work more efficiently than in the ;ter, because of the constant change in direction of effort; but in the 'mer they generally require an attendant to direct the reversal of their ›tion at the ends of the path.

6.7.09. The work in the straight path can only be used in bailing. ıis application requires no apparatus except a sheave and rope, but is ;ended with some inconvenience, as the rope and bucket have to be vered by the attendant. The work of animals is, therefore, most ıally employed by causing them to exert their tractive force in a cular path by means of horse-powers or horse-winches.

6.7.10. The horse-winch, as its name implies, is a hoisting machin and is frequently used for bailing small quantities of water. Th animal must reverse its direction of travel when the bucket reaches th

FIG. 187.

top, and again at the bottom. For this reason, an attendant is usuall required to direct the operations of the animal. Fig. 188 illustrates common form of horse-winch.

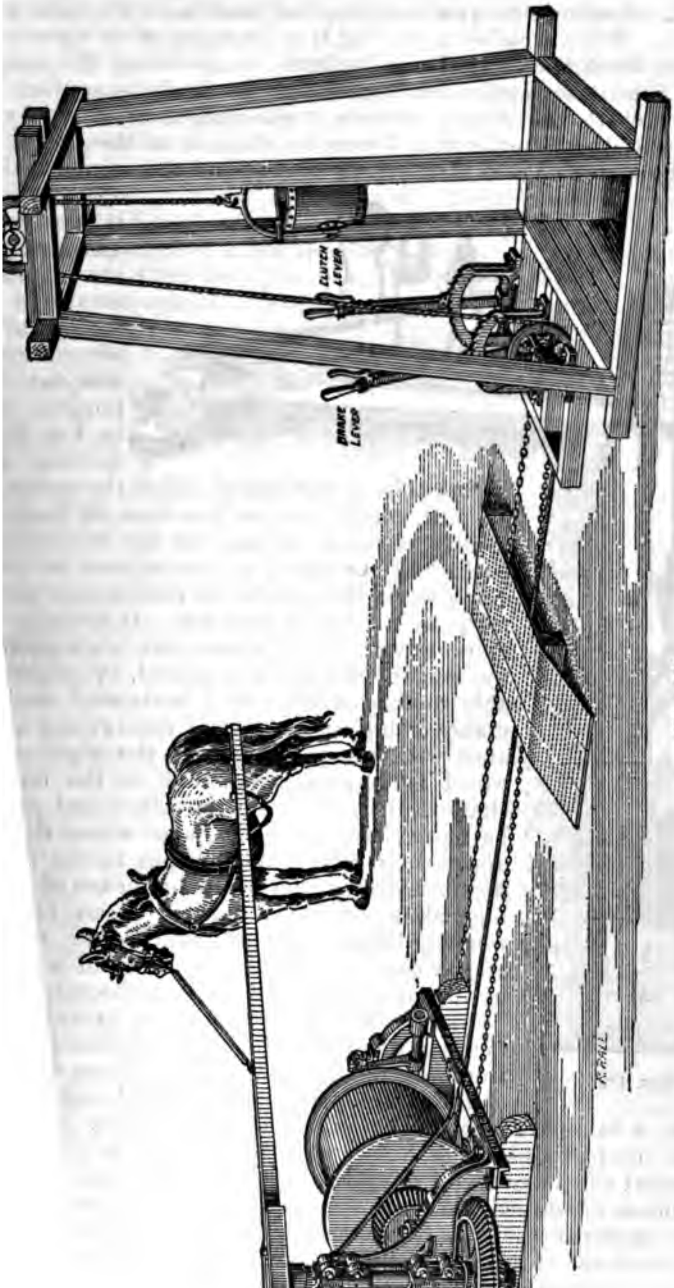


FIG. 188.

6.7.11. In the horse-power the animal maintains the same direct of travel. When applied to bailing it is arranged with a geared ho ing-drum fitted with a brake and clutch, or device for disengaging t gears. When the bucket reaches the top, the brake is applied and t animal stops. The clutch or gear is disengaged after emptying t bucket, and the latter is then lowered by means of the brake. Wh filled, the clutch or gear is again thrown in, and the animal started

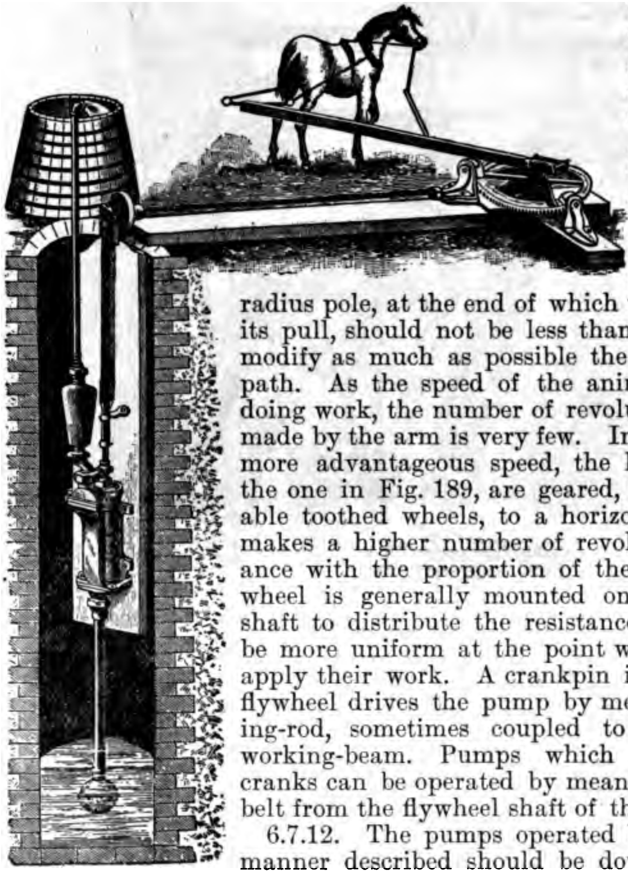


FIG. 189.

The horse-pow is, however, bett adapted to op ate pumps means of cran A usual for of horse-pow adapted to th purpose is show in Fig. 189. Th driving arm radius pole, at the end of which the animal exert its pull, should not be less than 16′ long, so as t modify as much as possible the curvature of th path. As the speed of the animal is limited i doing work, the number of revolutions per minut made by the arm is very few. In order to secure more advantageous speed, the horse-powers, lik the one in Fig. 189, are geared, by means of suit able toothed wheels, to a horizontal shaft, whic makes a higher number of revolutions in accord ance with the proportion of the gearing A fly wheel is generally mounted on the end of th shaft to distribute the resistance and cause it t be more uniform at the point where the animal apply their work. A crankpin in the side of th flywheel drives the pump by means of a connec ing-rod, sometimes coupled to an intermediat working-beam. Pumps which are fitted wit cranks can be operated by means of a pulley an belt from the flywheel shaft of the horse-power.

6.7.12. The pumps operated by animals in th manner described should be double-acting, or, single-acting, two pumps worked from opposite end of a working-beam should be used, or, instead of on of them, a balance weight. The difficulties of efficiently operating cen trifugal pumps by means of horses were pointed out in 6.2.13. Wher mechanical efficiency is not required, however, they may, on account o the uniform resistance and their simplicity, find application for raisin water to moderate heights by means of animals. Chinese pumps an water-elevators can also be readily operated by horse-powers, and caus a uniform resistance.

6.7.13. Where the work of men or animals is required for water-lif ing in mines, it is generally needed at once, so that there is no tim afforded for the design and construction of special machinery. Th plant should, for this reason, as well as on account of cheapness, l

posed as much as possible of apparatus which can be obtained ready ı a stock in the market.

7.14. The power of men or animals depends upon individual qualities ;rength, weight, and endurance, as well as upon the time occupied in ɛ. It also varies with the manner of application of the power, the ting temperature, and the amount and quality of food. The power or of work of an individual is greater with frequent intervals of rest, increases also with the period of rest. The average daily capacity of ın may be taken at about one twelfth of a horse-power, while exertions ıe short duration of a few seconds have been noted where the power ted for the time being exceeded one horse-power. The average er of a horse or mule is about one half of a mechanical horse-power. average power of cattle is less, and that of donkeys much less. As arked before, however, these data are subject to considerable varia-, due to difference in individual qualities and conditions.

SECTION VII.

CONCLUDING REMARKS ON MINE-DRAINAGE PLANTS.

CHAPTER I.

7.1.01. In providing for the drainage of a mine there are, after fixing upon the capacity, two things chiefly to be borne in mind. The first is the commercial efficiency of the installation, considered with due reference to the mining risk and the length of time that the plant will probably be in use. The second is the degree of safety against drowning out which the plant affords. Drainage tunnels can sometimes be used, where the conditions are favorable, to partially relieve an existing pumping-plant which has to handle a large quantity of water, by reducing the pumping height, and thereby either saving expense of operation, or enabling an existing pumping-plant to handle a larger quantity of water.

7.1.02. The capacity of a pumping-plant should be liberally measured, as upon it depends the welfare of the whole mine.

7.1.03. The best safeguards against the flooding of a mine are either large and rapid bailing-capacity, or an ample pump-compartment and a pumping-plant admitting of rapidly introducing and attaching to the piping movable reserve pumps kept in readiness at the surface for such emergencies.

7.1.04. Where sinking is abandoned for a long period, it is a good plan, where the conditions admit, to increase the capacity of the sump by running drifts, which, in case of short stoppages of the pumping-plant, retard the rise of water in the shaft, by the amount of time required to fill them.

7.1.05. In determining upon the general type of plant, the kind of power available or already at hand may be of importance. Where steam is the power adopted, and several kinds of fuel are available, the boiler-plant should be arranged with a view of using either of the fuels, as thereby the competition of the different dealers could be taken advantage of to secure fuel at more reasonable rates than otherwise. The price of fuel is generally higher the greater its evaporative effect; transportation, however, is generally the same per ton over the same route, so that the more high-priced may be the cheapest to get. But as prices vary the conditions may change, and it is, therefore, well to be prepared to take advantage of the conditions of the market. Boiler-plants should be of ample capacity, so that one or more of the boilers can be laid off for cleaning during regular operation, while all the boilers can be used when an extra flow of water is struck.

7.1.06. In case water-power is to be considered, its safety against stoppage from breaks in ditches, flumes, or pipe-lines is of vital importance. The possible occurrence of such accidents may necessitate a relay of steam-power to be kept in readiness, so as to prevent stoppage of pumps or bailing appliances.

7.1.07. Where electric transmission is available for operating pumps,

t is still to be considered that the burning out of an armature would ıang up the pumps connected therewith and expose the mine to the langer of flooding. Spare armatures, with shaft and all attachments omplete, should be on hand for immediate replacement of the one ›urnt out. The motors should be of such construction as to admit of apidly making repairs or changes.

7.1.08. In starting a shaft it is generally advisable to provide an ,mple pump-compartment, to afford space for pumps as well as for low-ring these or parts of them. It is generally not possible to determine ›eforehand which is commercially the more advantageous: to permit ,ll the water from different levels of the mine to collect at the sump, and ›ring it to the surface in as few lifts as the kind of pumps used admit ›f, or to collect the water at the different levels where it issues, and from here deliver it to the surface.

7.1.09. A preliminary plant is usually required before the plan for he final installation is decided upon. The appliances for preliminary ıse should be of a type and size most readily and quickly obtainable in he market.

7.1.10. Where the quantity of water that may be encountered is ›eyond conjecture, as is often the case, the Cornish system is not advis-ıble, as it does not generally lend itself to considerable increase of :apacity without discarding the entire machinery. It is also inefficient vhere variable quantities of water are taken in at different levels, because :he pumps have to be adjusted to their proper relative capacity by per-nitting back-flow of water already pumped. Where a Cornish plant ıas been installed at great cost for large capacity, its degree of efficiency, :ommercially considered, will decrease considerably when the quantity of water that it is called upon to handle decreases, much more so than that of direct-driven pumping-plants.

7.1.11. In by far the greatest number of cases the use of direct-driven pumps will be the most advisable; it is impracticable, however, to consider, in a general treatise, the conditions that might influence the choice of the most suitable plant. Each special case generally develops so many characteristic features, that only a careful study of the conditions, by experienced and trained engineers, can lead to satisfactory results.

7.1.12. The statements of efficiency of pumps, engines, compressors, etc., contained in the many trade catalogues floating around through the mining settlements, must be taken very cautiously. The same applies to many of the so-called practical tests of pumping-plants. Such data should only be accepted when a full account of the test and a complete description of the methods and appliances used in observation, together with detailed data of observations, is given by parties who are known to be competent and disinterested experimenters.

7.1.13. Generally, plans and complete specifications having reference to the quality of the work are required, in order to obtain good workmanship under the conditions of keen competition so prevalent now.

SECTION VIII.

APPENDIX.

CHAPTER I.

Water-Raising Machinery for Irrigation or Land Drainage.

8.1.01. *General Remarks.* As stated in the Preface, it has been considered that this Bulletin would be incomplete without some reference to water-raising machinery for other than mine-drainage purposes. There are useful machines for raising water which can find no application in draining mines, but which may be of interest because they can serve, under certain conditions, to furnish a supply of water, when required, for other useful purposes, in mining as well as for irrigation or land drainage.

8.1.02. A feature which usually attaches to such water-raising machinery is that, except perhaps quite often in land drainage, it is not required to operate at capacities varying widely from those at which it is designed to give the best mechanical efficiency. Generally, also, the conditions admit of varying the capacity by varying the time of operation of the machinery.

8.1.03. The two sources of water supply to be considered for the purposes of irrigation or mining are natural or artificial watercourses and bored wells. The chief sources for mining supply are watercourses. In the mountainous regions wells are generally of smaller capacity than in the great valleys, and, therefore, are only rarely utilized.

8.1.04. Frequently it is not possible to bring the water by means of canals, ditches, flumes, or inverted siphons to the places where it is required, and then pumping must be resorted to, and the water conveyed under pressure in pipes to its destination. Sometimes, also, the first cost, with interest and maintenance expenses of an artificial watercourse, exceeds the corresponding items plus the operating expenses of a pumping-plant. For land drainage, canals and ditches are often impracticable, and the water has to be raised by machinery.

8.1.05. The sources of power for operating such water-raising machinery may be water-power, steam and gas engines, wind, or animals. Windmills have a wide application for the familiar small irrigation plants. Horses, mules, and cattle are used only to a limited extent, while gas engines have recently been applied quite extensively for small operations. For larger plants only water- or steam-power can be considered. These may be applied to drive the water-lifting machinery, either directly, or, as in the case of reciprocating or centrifugal pumps, by means of transmission, such as wire ropes, compressed air, or electricity. It is often most advantageous to subdivide the transmission, so as to operate several smaller favorably located pumping units from one large central power-plant.

8.1.06. The kind of water-raising machinery employed may consist

of reciprocating pumps, including deep-well and direct-driven pumps, centrifugal pumps, water-elevators, Chinese pumps, air-lift pumps, bucket-wheels, paddle-wheels, or rams. The bulk of these, constituting

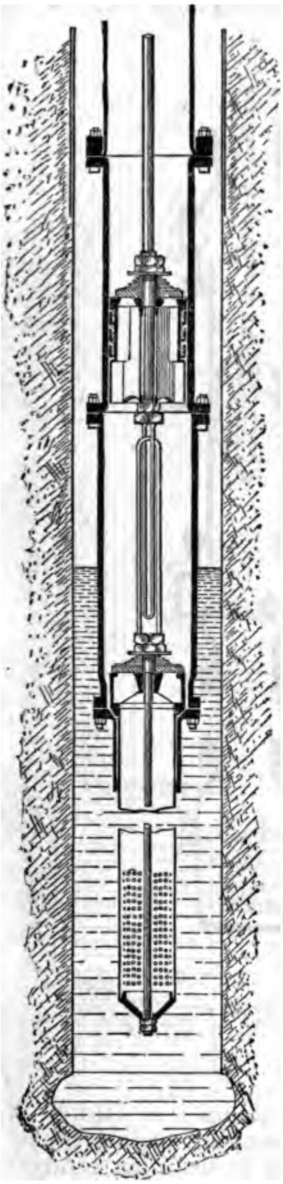


FIG. 190.

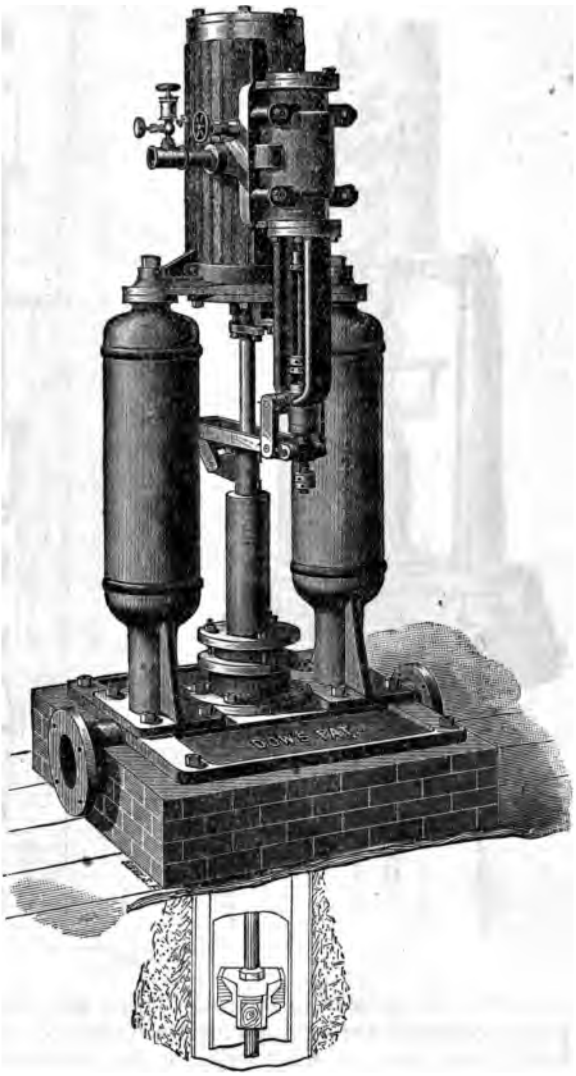


FIG. 191.

those which find application in mine drainage, have been described in the body of this Bulletin. It remains yet to describe more in detail those machines not treated before, viz.: certain kinds of reciprocating

pumps, bucket-wheels, paddle-wheels, and rams, together with such power appliances as may be particularly suited to operate them, and also to speak of the machines already described in connection with their application to irrigation and drainage, and of the methods and means for driving them.

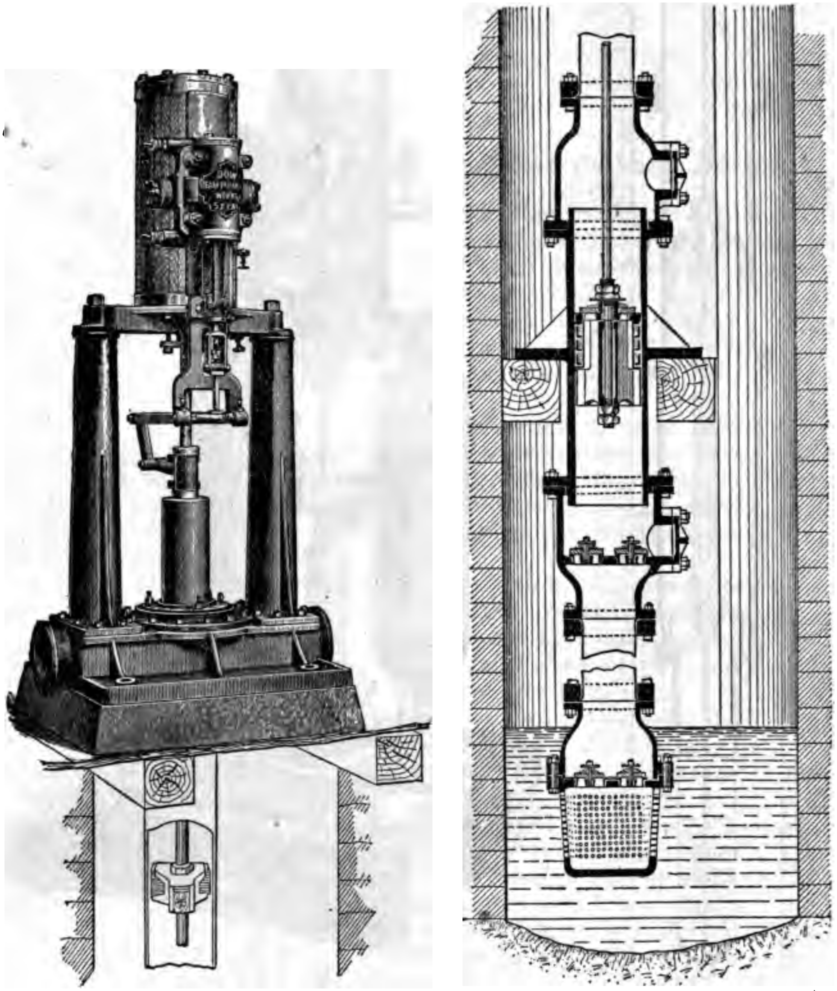


FIG. 192.

8.1.07. *Reciprocating Pumps.* These may be plunger or bucket-lift pumps operated through pumprods, either for pumping against higher heads from tube- or shaft-wells, or for low heads in draining land, as used in Holland; or, they may be direct-driven pumps, similar to the types used in mine drainage, but permitted to be made lighter and with proportionally smaller steam cylinders to suit the generally lower pumping-head.

8.1.08. Rod-actuated well-pumps find a wide application on this

ıst. They exist in various forms, and of all capacities, from the ıall windmill pump to the large deep-well pump driven by a com-und engine, and similar in many respects to a mine-drainage pump.

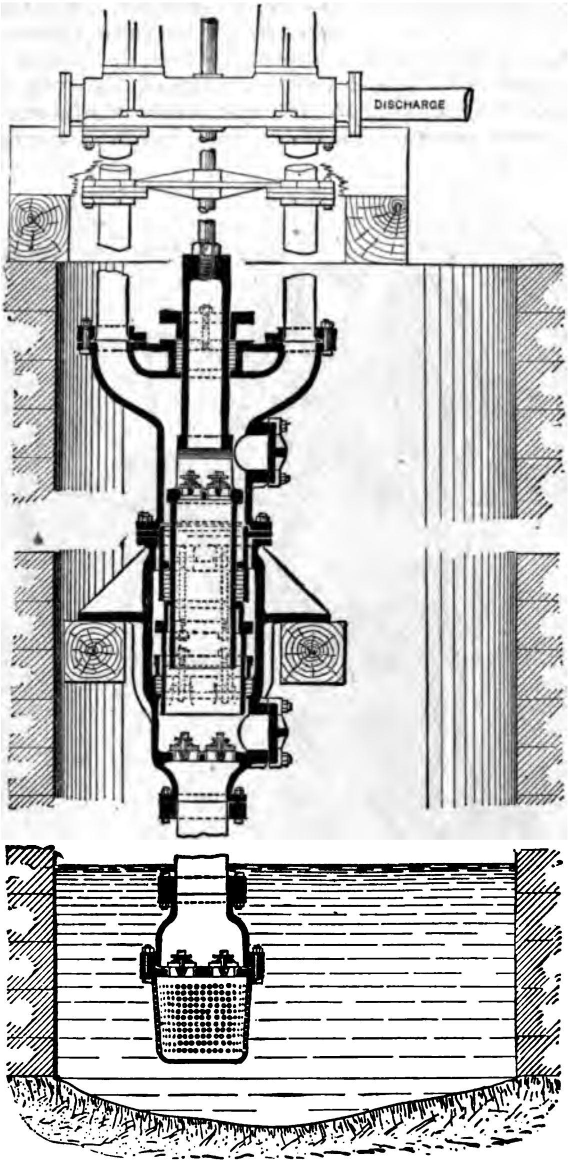


FIG. 193.

8.1.09. Figs. 190 and 191 illustrate a large-tube well-pump and the am engine for operating it from the surface. The pump-column car-s at the upper end a head, with outlet at side and stuffing-box at the ›, through which passes a plunger, the area of which is equal to half

that of the pump-bucket. By this construction the pump is made double-acting, so that it discharges equal amounts of water during both strokes. It is to be noted, however, that the pump resistance itself is not equal for the two strokes, because the plunger, being high above the bucket, is not subjected on its lower face to the same pressure per square inch as the top of the bucket. This defect will be less if the water be raised to a considerable height above the top of the well, and it can be entirely overcome by making the plunger larger in diameter to compensate for the lower pressure, in which case, however, the discharge will

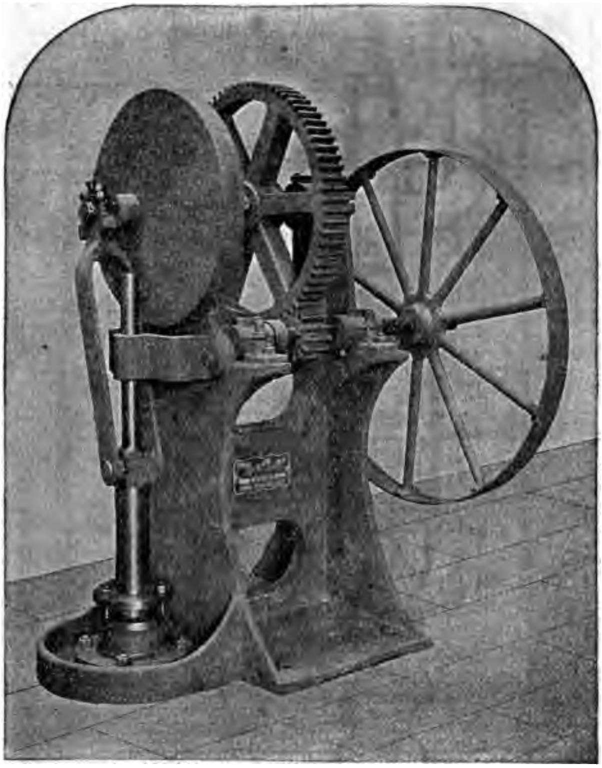


FIG. 194.

be more unequal. Continuing the plunger of half the area of the bucket down to the latter will generally be no advantage, on account of the weight of the plunger counterbalancing the gain in water pressure. The suction-valve-seat and suction-pipe hang simply by their own weight in the bottom of the sleeve bolted below the suction-valve-chamber. The suction-valve is provided with a long, upwardly projecting, rigid link, which hooks into a similar link depending from the bottom of the pump-bucket. The length and width of the links are such that they are out of contact while the pump is in running adjustment. When repairs become necessary and the bucket is hauled up, the suction-valve and suction-pipe follow it. Where there is much sand

e water the bucket leathers naturally wear out in a very short Fig. 192 shows a bucket pump, and Fig. 193 a differential plunger) for raising water from a shaft-well. The descriptions of similar ting devices in preceding sections of this Bulletin make further nations of the illustrations superfluous.

.10. Where electric motors or gasoline engines are used to operate well pumps, the top of the tube is arranged with suitable gearing, Fig. 194, the pulley of which is driven by belting from the motor. ı driven by electric motors, the resistance should be more uniform is afforded by simple equalization of the two strokes. If two wells

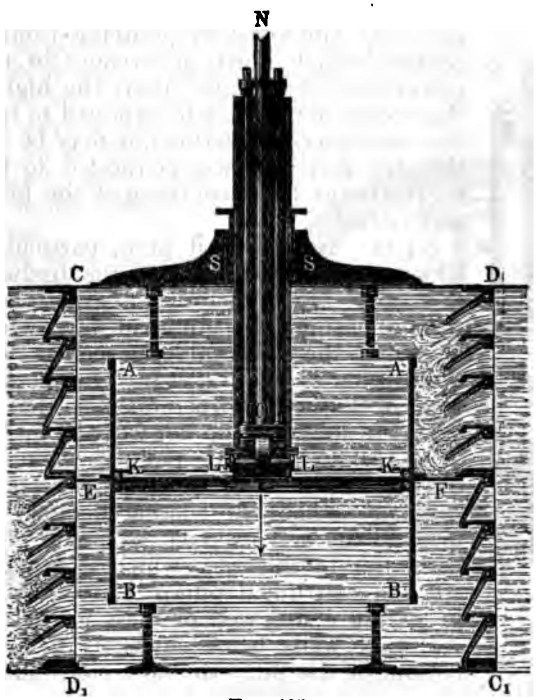


FIG. 195.

pumps at right angles cannot be used, some such arrangement as ibed in 2.5.21 could be applied.

.11. A well-known but interesting reciprocating pump designed nd-drainage purposes by the Dutch engineer Fynje, is the so-called ›ump, a vertical section of which is shown in Fig. 195. This pump vays vertical and double-acting, and its characteristic feature is the ıgement of the suction- and discharge-valves, which are disposed in site sides of a box, surrounding the pump-barrel, and divided ontally at the middle by the partition *F* into an upper and a lower ıber. Pumps of this kind are inserted in or built against a bulk- separating the supply-water from the discharge-water. They are ; of very large capacity.

.12. *Centrifugal Pumps.* These have been described in 6.2.01 to 4, but their application to irrigation and land drainage, as well as

to analogous purposes in mining, admits of so much more favorable arrangement and connection with power machinery than for mine drainage, that further reference to them is of interest. When used to pump from open watercourses they are often of very large size and capacity; for example, the five pumps at Khatetbeh, Egypt, built by Farcot, of Paris, for irrigating the province of Behera. Each of these five pumps has a capacity of 140,000,000 gals. in twenty-four hours, at forty revolutions per minute, and at a lift of 10′. These are the largest centrifugal pumps ever built, the runners being over 12′ in diameter.

8.1.13. Centrifugal pumps can generally be operated when submerged, except direct-driven centrifugal pumps with horizontal axes, such as are generally employed in pumping from open watercourses, which must, on account of the connected power-plant, be located above the highest level that the suction-water may be expected to reach. Where the runner-axis is vertical, it may be made so long that the driving-power connected to its upper end shall always be above reach of the highest suction-water-level.

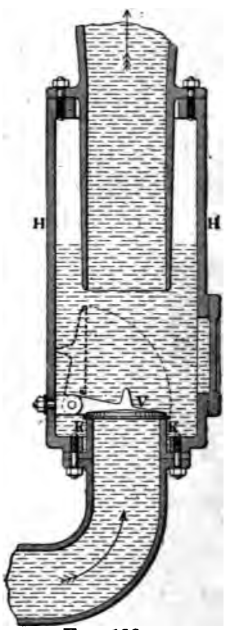


FIG. 196.

8.1.14. It is a good plan, particularly for high lifts, to use a check-valve in the discharge-pipe, and to arrange an air-chamber above it, as in Fig. 196, so as to cushion the column of water which falls back and closes the check-valve, as soon as the pump slows down below a certain speed. The check-valve swings clear of the current when open, so that the sand and gravel in the water do not wear its face out too soon.

8.1.15. Centrifugal pumps, when employed to draw water from bored wells, necessarily do so by suction. When the suction-distance to the water-level in the well exceeds the power of the pump to lift water in this way, which is generally at about 20′, the centrifugal pump is placed lower down by preparing a dug well or shaft for its reception, several tube wells being sunk 50′ to 150′ below the bottom of the pit. In most cases such pumps are arranged with a vertical axis, as in Fig. 168, the power being applied at the surface.

8.1.16. Foot-valves cannot be used in the tube wells, on account of lack of space there. Therefore, steam-ejectors or other appliances are required to prime the pumps. The check-valve in the discharge-pipe, if tight, will hold the water in the pump for a time.

8.1.17. Well-water frequently contains a large amount of carbonic acid, which becomes liberated at the upper end of the suction-pipe, and interferes with the action of the pump, if it is not carried along by the force of the current or removed automatically by special appliances, such as a small air-pump driven from the axis of the pump. Pockets or valves, where the gas may lodge, should therefore be avoided in suction-pipes.

8.1.18. One difficulty with centrifugal pumps having long vertical shafts attached to them, is the friction due to the weight of these shafts, and the unbalanced pressure on the pump disk. Where electric motors are used to drive the pumps, the long vertically extended shafts can be

avoided, if a motor with vertical axis can be obtained for connection close to the pump.

8.1.19. *Power, and Its Transmission to Reciprocating and Centrifugal Pumps.* Steam-, and sometimes low-head water-power operating by means of turbines, can be applied for driving directly reciprocating and centrifugal pumps.

8.1.20. A power-plant can often be located more advantageously to its operating expense at a distance from the pumping-plant or -plants, either by reason of cheaper fuel, due to saving in freight, or on account of the availability of a water-power. In such cases the power must be transmitted over a distance to the pumping-plant.

8.1.21. It is generally advisable, then, if the power be adequate to drive a number of pumping-plants, to operate them all from one large power-plant, for the reason that a larger plant can be equipped with machinery of higher mechanical efficiency, while the cost of attendance will be less in proportion to the number of pumping subdivisions.

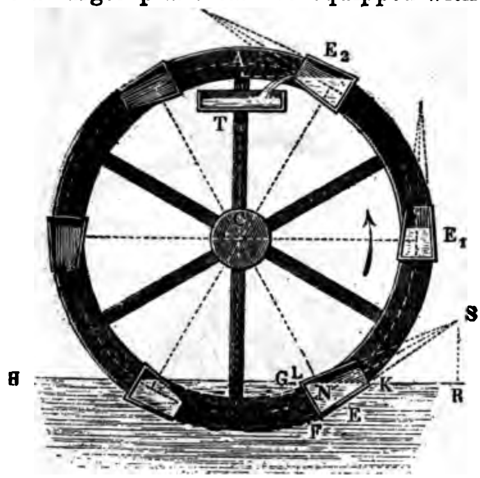


Fig. 197.

8.1.22. Wire rope transmissions would have but a rare application, the distances to which they are suited being limited.

8.1.23. Compressed air, reheated at the pump engines, might be the best method in cases where the pumping is variable, where a good efficiency is desirable, and where steam is the prime motive power; also, where the distance of transmission is not too great, and where reciprocating pumps, which lend themselves best to operation by steam or compressed air, constitute the water-raising machinery.

8.1.24. For great distances, and for operating high-speed, rotary, water-raising machines, like centrifugal pumps, electricity is in general the best mode of transmission. It is not well adapted to cases where great variation of speed is required.

8.1.25. Occasionally, small portable plants, consisting of a centrifugal pump with steam engine and boiler on wheels, find application. These are moved about by means of horses from place to place along a line of ditches or canals. Sometimes a pumping-plant is mounted on a barge floated on the canal.

8.1.26. *Bucket-Wheels.* One of the oldest water-raising appliances for moderate lifts, is the bucket-wheel. Fig. 197 shows a common form. The wheel is rotated either by animal- or engine-power, or, as is most usually the case, by the current of a stream from which it lifts the water, being fitted in this case with paddles. The paddles of the wheel are best made curved, or bent at an angle for the sake of simplicity of construction, as in Fig. 198, so that they leave the water in a vertical direction. The efficiency of paddle-wheels, particularly where running

in an unconfined current, is very low. The wheels require to be of great width to obtain even small amounts of power. Where the water-level of a rapid stream does not vary much, stream wheels, though inefficient mechanically, afford a very cheap source of power for raising moderate quantities of water. Where the streams can be confined and dammed so as to raise the water in front and produce a head which acts on the wheel by its weight, the efficiency is much better, and the power much greater, if the wheel is properly constructed. Wheels so situated make a greater number of revolutions, because the paddles then travel with the same velocity as the water which leaves the wheel.

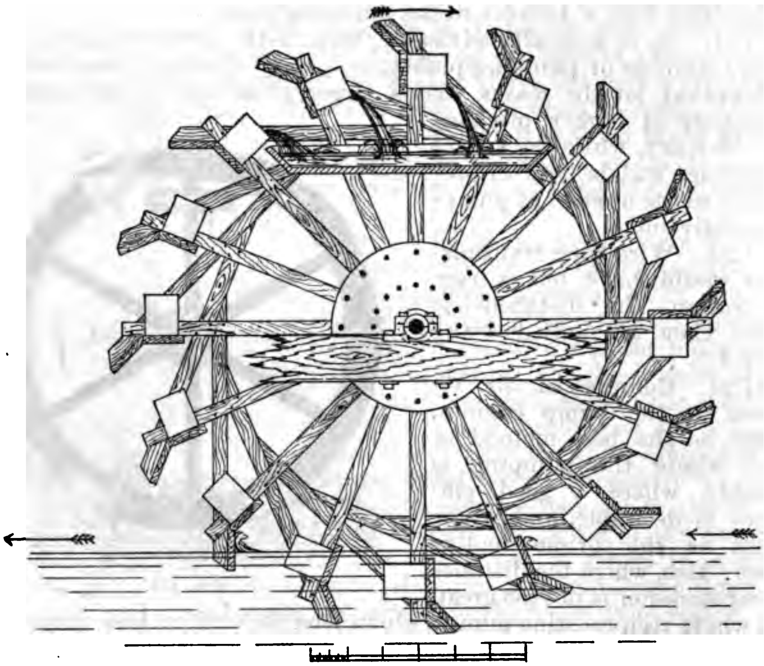


FIG. 198.

8.1.27. Bucket-wheels are suitable only for moderate capacities. The buckets are often made only of common tin cans nailed to the wooden arms or rim of the paddle-wheel.

8.1.28. In fixing the diameter of bucket-wheels, it must be remembered that the level of the discharge-trough is considerably below the top of the wheel. Also, that the distributing-troughs must have sufficient grade to deliver the required quantity of water at more or less distance in a given time.

8.1.29. *Paddle-Wheels.* Where large quantities of water are to be lifted only to a small height, like in some of the drainage undertakings in Holland, paddle-wheels revolved by engine-power in a curb, as in Fig. 199, give very good results. The curb should fit the wheel as close as possible without touching it. The paddles should be inclined so that the water will flow from their surface rapidly, and not be thrown higher than is necessary. Such wheels should be made of iron; otherwise, they

will swell or shrink and either jam in the curb or leave too much clearance for back leakage. The back-flow of water is prevented, when the wheel is stopped, by a check-gate at *a*.

8.1.30. *Hydraulic Rams.* The hydraulic ram is a machine in which a body of water in a pipe under a generally low drive-head intermittently acquires velocity and energy of motion, by virtue of which a part of the water is raised to a height generally greater than the drive-head, while a larger part is permitted to escape to a lower level during the time that the water acquires its velocity. Like in any other utilization of water-

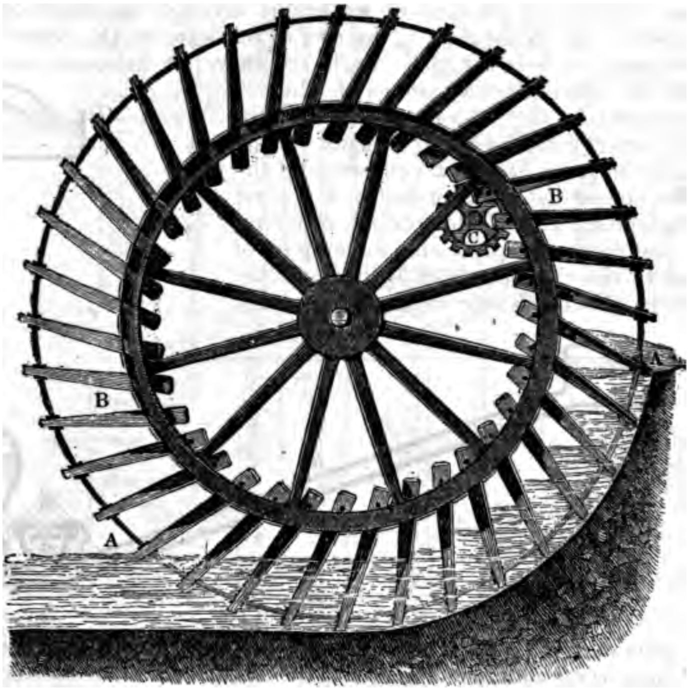


FIG. 199.

power, the conditions for the operation of a ram require an available fall for the discharge of power-water below the level of the supply-reservoir.

8.1.31. The essential arrangement of a hydraulic ram is as shown schematically by Fig. 200, in which *A* is the supply-reservoir, from which water is to be raised to the elevation *H*. The drive-pipe *B* enters the air-chamber *C* of the ram at the bottom, where the opening is provided with a check-valve *D*, to arrest the back-flow of the water discharged into the air-chamber. The discharge-pipe *E* leads from a low point of the air-chamber, in the manner as described in connection with pumps. Close to where the drive-pipe enters the air-chamber, there is located a valve-chamber *F*, its lower end open to the pipe and its cover on top fitted with an inwardly and downwardly opening check-valve *G*, called the overflow-valve.

8.1.32. To explain the operation of the machine, suppose, first, that

the valves D and G are both closed, and that the discharge-pipe E, as well as the drive-pipe D, are filled with water, while the air-chamber C contains water and air. If, now, the overflow-valve G is opened by forcing it down from its seat, it will remain open by its own weight for a short time, while water will start to flow from the opening, and the water in the drive-pipe will acquire velocity until the pressure below the valve will close it suddenly, so that at the lower end of the drive-pipe there occurs a rise of pressure, which, if sufficient, will open the discharge-valve D against the pressure on its upper surface and force water into the air-chamber, compressing the air therein, which in turn drives an equivalent amount of water out through the discharge-pipe and delivers it at the level L. The rise in pressure at the lower end of the drive-pipe and below the discharge-valve D increases with the length of the drive-pipe B, and with the velocity acquired by the water contained in it. When the energy of the water flowing in the drive-pipe has spent itself in compressing the air in the chamber C, the pressure of the air on re-expanding, and while forcing water up through the discharge-pipe, also forces part of the water in the chamber back into the drive-pipe, before the discharge-valve D has time

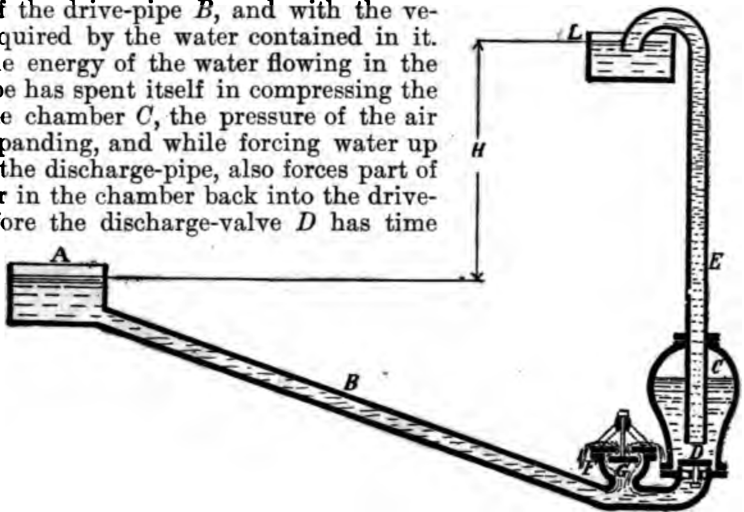


FIG. 200.

to close, thus starting a backward flow in the drive-pipe. The discharge-valve D, however, suddenly closes, and the acquired return motion of the water in the drive-pipe reduces the pressure at its lower end and below the overflow-valve G sufficiently, so that it will open by the pressure of the atmosphere combined with its own weight, and thus permit water to escape from the drive-pipe, thereby again starting a flow toward the ram, when the operations as before described are repeated continuously.

8.1.33. The length of the drive-pipe has an important bearing on the action of a ram. It should be the longer the higher the water is to be raised by a given fall of power-water. It can be shorter, if this fall constitutes a large proportion of the lift, or equals or exceeds it. There should be as few bends and obstructions as possible in the drive-pipe.

8.1.34. The weight of the overflow-valve should generally be small, but should be capable of adjustment, so that the duration of overflow and the velocity acquired by the water in the drive-pipe can be regulated to suit the lift. The overflow-valve and discharge-valve should be located as close together as possible.

8.1.35. The ordinary rams obtainable in the market are only suitable

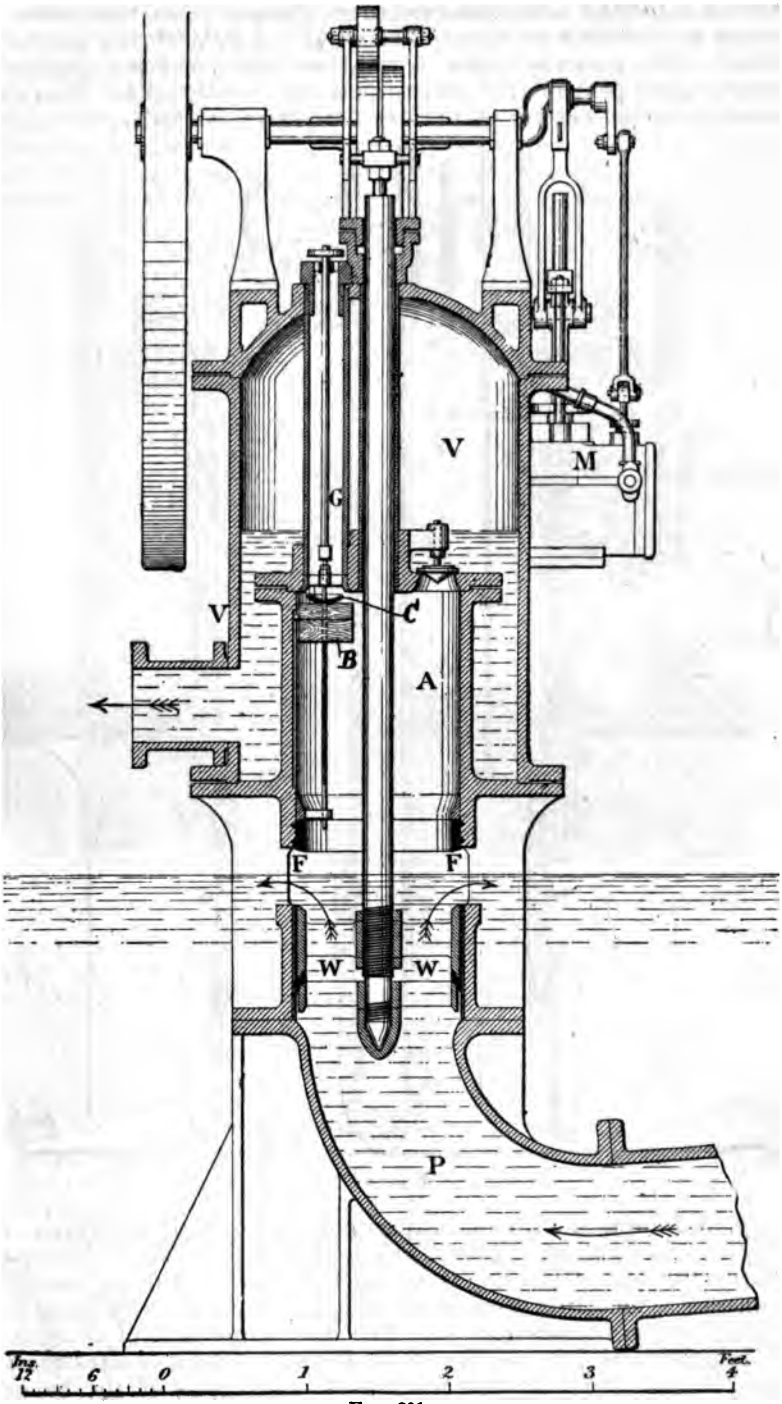


FIG. 201.

for small capacities and moderate lifts. Special rams have been co structed to meet such conditions as a supply of 300,000 gals. per day.

8.1.36. The common forms of rams are very inefficient applian mechanically, particularly when used for higher lifts. The bl occurring on the closing of the overflow-valve causes a great loss

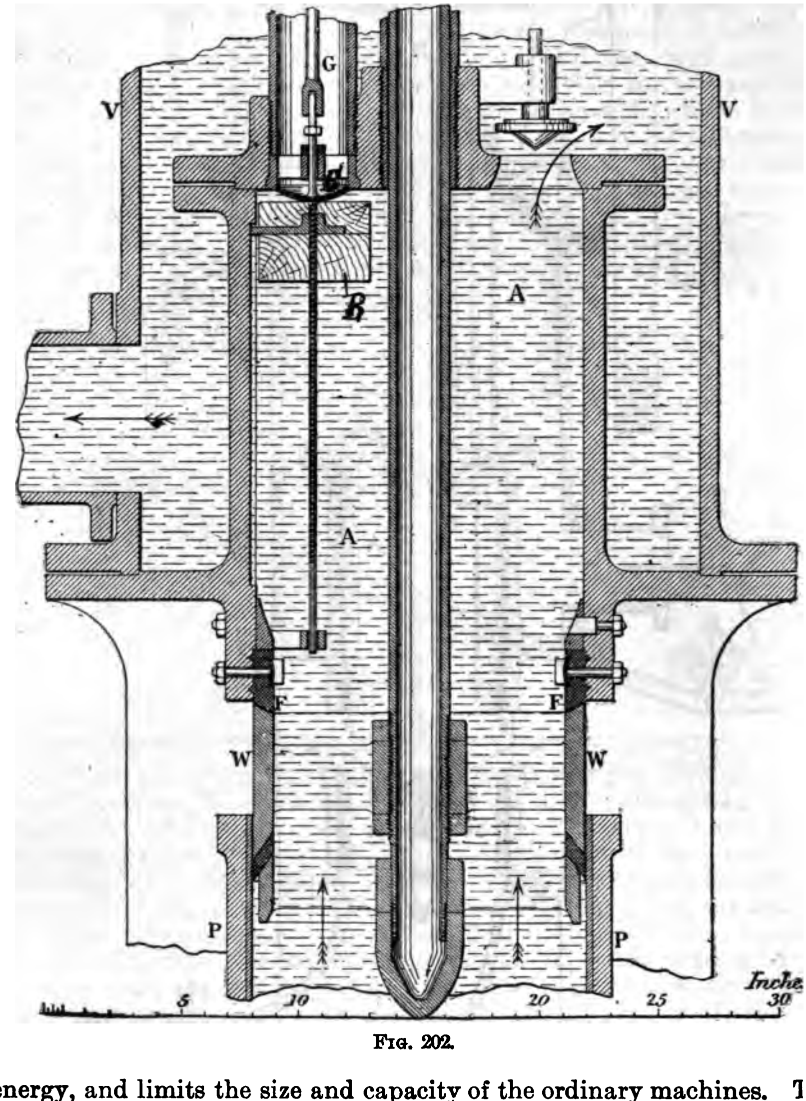


FIG. 202.

energy, and limits the size and capacity of the ordinary machines. T pretty general impression prevails that the blow or shock on the closi of the overflow-valve is a necessary function without which a ram cou not operate. That this is erroneous is shown by some very large hi lift rams of recent construction. The most important of these is t ram designed and patented by H. D. Pearsall, which is illustrated Figs. 201 and 202. In this machine the functions of the balan

overflow-valve *W* are made directly independent of the action of the water in the drive-pipe. The opening and closing of *W* is controlled by a small compressed-air engine *M* mounted on the air-chamber *V* and operated by the compressed air contained therein, the amount used being replenished at each pulsation by air trapped in the chamber *A*. This chamber, which is called the ante-chamber, is kept filled with air at atmospheric pressure coming in through the tube *G* up to the time that the water on rising in *A* reaches the wooden float *B* with the valve *C* and closes the lower end of *G*, thus cutting off communication with the outer air. The air remaining in *A* is compressed until it overbalances the pressure on top of the discharge-valves, when it rises into the air-chamber in advance of the water. The discharge of the water from

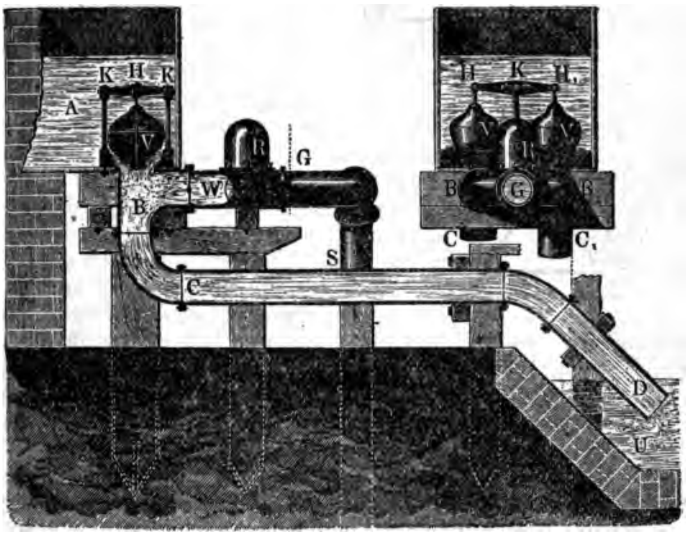


FIG. 203.

V is effected by the compressed air in the same manner as in the ordinary rams. As the column of water in *A* and in the drive-pipe *P* falls back the float *B* and valve *C* sink, uncovering the lower end of *G* and admitting air into *A*. At the same time the compressed-air engine *M* again opens the overflow-valve *W*, and the water in *P* begins to acquire velocity for a new impulse. Instead of operating the valve *W* by a compressed-air engine, it could also be worked by a small waterwheel driven by a nozzle from the discharge-pipe.

8.1.37. None of the rams heretofore described are suitable for raising water by suction, and they require to be placed at the level of the overflow from the drive-pipe. It is, however, often convenient, particularly for irrigation and land-drainage purposes, to locate the ram at a higher level, in which case it must necessarily draw the water up from the supply-reservoir.

8.1.38. A double-acting ram of this description was designed by the Belgian engineer Leblanc, for raising water from a level below that of the discharge, by means of an independent supply of power-water situated at a higher level. It is illustrated in Fig. 203. *A* is the

supply-reservoir for the power-water; *B C D* the discharge-pipe leading therefrom and corresponding to the drive-pipe of the ordinary ram. It might in this arrangement be properly termed the draft-pipe. *S G* is the upper part of the suction-pipe leading up from the excavation to be drained. The power-water here flows past the open valve *V* into the

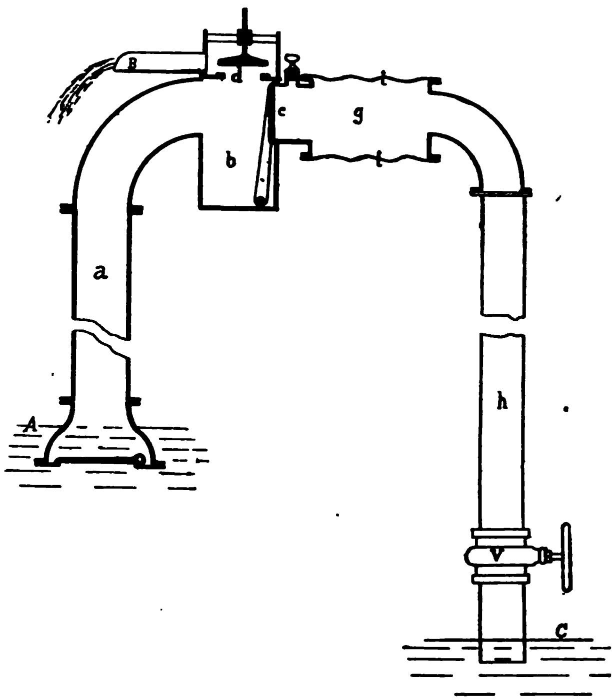


FIG. 204.

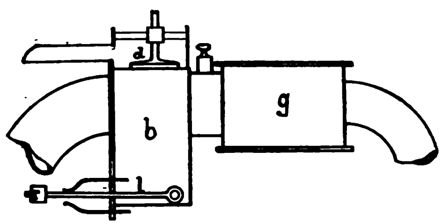


FIG. 205.

discharge-pipe *B C D*, therein acquiring velocity, increasing until the pressure beneath the nearly buoyant valve *V* is reduced so that the pressure above it forces it to its seat. As the water in *B C D* continues its motion it will create a suction effect in front of the suction-valve *W*, which then opens and allows water from the suction-pipe *S G* to follow the water in *B C D*. As soon as the energy of flow has spent itself, the column in both pipes begins a retrograde motion, and the valve *W* is suddenly closed, thereby cutting off the exit of the water in *B C D*, which then spends its remaining energy of return flow in forcing open

ıe valve V, and thus prepares the conditions for the next discharge ow in $B\ C\ D$.

8.1.39. The machine illustrated is made double-acting by the use of wo discharge-pipes, two suction-valves W, and two arresting-valves V nd V', the latter being balanced by suspension from the opposite ends f a double-armed lever K. By this arrangement a more perfect funcioning of the apparatus is secured, because the discharge flow in one lischarge-pipe occurs at the same time as the more feeble return flow in he other, so that the more powerful suction-action of the discharge, by losing its arresting-valve V, will, at the same time, aid in lifting the other valve V' over the returning column in the other discharge-pipe.

8.1.40. Another machine of the ram type, which also raises water by suction, but which is designed to work under different conditions than the Leblanc ram, is the so-called siphon water-elevator of Lemichel & Co. of Paris, which was exhibited at the Midwinter Fair in San Francisco. This machine, which is illustrated in Fig. 204, is intended to raise water from a supply at the level A to a higher level B, by means of a discharge to a lower level C; these conditions being similar to those under which the ordinary ram is called on to operate, but with the difference that in this case the machine raises water by suction, and is located at the highest level B, identical with that of the delivery of the water intended to be raised for a useful purpose.

8.1.41. This machine employs the principles of action both of the ram and of the siphon, and should, therefore, more properly be called the "siphon ram" instead of "siphon elevator."

8.1.42. The operation of the machine is as follows: On opening the valve V in the discharge- or draft-pipe h, Fig. 204, the water in the siphon begins to move in the direction of the discharge level C, falling in h and rising in the suction-pipe a, and acquiring velocity of flow until the force of the latter is sufficient to close the check-valve c in the chamber b. The exit of the moving water in a being thus cut off suddenly, the momentum of the water spends itself in raising the outlet-valve d and discharging a portion of the column over the edge of the valve-seat. During this time the downward momentum of the water in the discharge-column h causes a reduction of pressure within the regulator g (which here performs the functions of the air-chamber in the ordinary ram), so that the elastic corrugated heads $t\ t_1$ are forced inward by the overpressure of the atmosphere until the energy of the water in h s spent, when a return flow takes place toward the check-valve c, which ıow opens through the combined action of the return flow both in h and n a, assisted by the weight r on the level l, Fig. 205. The functions lescribed take place in a very brief period of time, the number of pulsaions being from 150 to 400 per minute. The chamber g, with elastic ıeads, is here substituted for the air-chamber on the ordinary ram, because under the low pressure the air would not have much cushioning effect and would also cause the pulsations to be too slow. The air, which is liberated at the exceedingly low pressure at the highest point, ust like in a siphon, is here expelled with the water through the discharge-valve d. If this were not the case the apparatus would not operate for many minutes.

8.1.43. It is claimed that by this machine the water may be raised at sea-level to a height of about 30′ above the supply-reservoir A. For greater lifts a series of superposed siphons may be used, the upper ones

decreasing regularly in capacity, as they can raise only a part of the water raised by the siphon below them.

8.1.44. Fig. 206 shows an application of the siphon ram or elevator, in which the water delivered to irrigate land below a main ditch is utilized to raise a less quantity of water to a small ditch at a higher level for the purpose of irrigating land situated above the main ditch.

8.1.45. The siphon ram is offered in capacities of from 250 to 3,000,000 gals. per twenty-four hours.

8.1.46. All rams, in order to operate efficiently, should be specially designed to suit the conditions under which they are expected to work. They will work efficiently only within narrow limits of variation of capacity, because the proper period of the pulsations is fixed by the proportions of lift to fall, and the lengths of the pipes.

8.1.47. In obtaining a supply of water for useful purposes, the question often arises as to which is the cheapest, both in first cost and in operating expense: a long ditch-line or flume, or a shorter one starting at and delivering the water to a lower level, in combination with a pumping-plant to bring the water up the remaining height to the required level. It must also be considered whether it is necessary to raise all the water to the entire elevation, and if part of it may not be delivered at the lower level accessible by the shorter ditch.

FIG. 206.

8.1.48. It is to be determined also whether such a pumping-plant is required to operate during the entire year, or only for a part of the time. Like mine-draining by pumps, the probable number of years during which the plant will be needed is also a factor which enters into the choice of arrangement.

8.1.49. It is impossible, in a treatise of this kind, to give more than suggestions as to apparatus and mode of operating it which are best suited to the requirements. Conditions in practice are so varied and present so many unforeseen problems that it would go beyond the scope of this Bulletin to attempt detailed consideration of particular cases. The proper treatment of such can only be carried out in special articles devoted to each case.

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V

CALIFORNIA STATE MINING BUREAU.

J. J. CRAWFORD, State Mineralogist.

BULLETIN No. 10. SAN FRANCISCO, SEPTEMBER, 1896.

A BIBLIOGRAPHY

RELATING TO THE

GEOLOGY, PALÆONTOLOGY, AND MINERAL RESOURCES

OF

CALIFORNIA.

By ANTHONY W. VOGDES, *Captain Fifth Artillery, U. S. A.*,

Fellow American Geological Society, American Association for the Advancement of Science; Member of the New York Academy of Sciences; also of the Georgia, Philadelphia, Chicago, and California Academies of Natural Sciences.

SACRAMENTO:

A. J. JOHNSTON, : : : : : : : SUPT. STATE PRINTING.

1896.

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Publications of Scientific Societies, and Periodicals.

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Publications of State Geological Surveys other than that of California.

PART V.

Miscellaneous Publications.

LETTER OF TRANSMITTAL.

HON. J. J. CRAWFORD, *State Mineralogist:*

I have the honor to submit this bibliography for publication by the State Mining Bureau, with the following brief remarks:

The literature relating to the natural resources of California is widely scattered, and, to a great extent, inaccessible to any one but the specialist.

The few descriptions of fossils printed in the State Geological Reports were issued nearly thirty years ago. Since that date a large number of papers on geology, palæontology, and descriptions of local mining regions have appeared, either in the transactions of learned societies or in special publications with but a limited distribution. In many cases these descriptions have been brief, and those of fossils without illustrations.

Besides these, there are many articles incorporated in the official publications of the United States, and in volumes whose very existence is almost unknown to the general reader.

I have labored to bring this mass of literature together and make it accessible to the student and general reader. Some may ask, What is the advantage of such a catalogue? But let them take up any special line of investigation, and the first thing wanted will be a list of books of reference to know what has been published on the subject.

To the compiler such compilations are dry and laborious, and many think afterward I could do better; but let all those who think so, labor to improve this catalogue.

The palæontologist has to deal with the different species under each genus. I have, therefore, included a full list of fossils under each reference, which will save the student many a weary

hour of laborious research through many volumes and transactions of learned societies.

The catalogue has been arranged under different heads, such as State geological reports, transactions of learned societies, etc., which will give the student a direct reference to the contents of different publications.

The palæontology of California differs greatly from that of the Atlantic States in the existence of an extensive bed of the Tertiary formation, with but few of the older formations, indicating that the elevation of the Pacific Coast was chiefly made since the Mesozoic age, and a great part of it as late as the Quaternary. Nearly all the coast ranges and the low foothills of the Sierra Nevada are covered with thick beds which contain fossils identical with living species, with others extinct along the Californian shores, but living farther to the north or south.

To make a complete catalogue, works on recent conchology of the Pacific Coast should be included, but the author has deemed it best to omit the most of them.

Part IV of the catalogue contains an alphabetical list of miscellaneous publications. Many of them are references to early reports on gold and other minerals, including trips to the gold fields of California. All of these are not strictly geological reports, but now and then they contain valuable references to local geology. The author regrets that he has been unable to give many notes in this part, most of the works being inaccessible.

ANTHONY W. VOGDES.

Fort Mason, San Francisco, Cal., September 1, 1896.

A BIBLIOGRAPHY

RELATING TO THE

GEOLOGY, PALÆONTOLOGY, AND MINERAL RESOURCES

OF CALIFORNIA.

PART I.

Publications of the State of California.

FIRST GEOLOGICAL SURVEY OF CALIFORNIA.

DR. JOHN B. TRASK, State Geologist.

Report of the Special Committee in favor of a Geological Survey of California. Submitted by Mr. Randall, April 24, 1851. 19 pp.

Report of 1853, Geology of the Sierra Nevada or California Range; by John B. Trask. Sacramento, 1853. 31 pp. (2,000 copies printed.)

Report on the Geology of the Coast Mountains, embracing their agricultural resources and mineral productions, also portions of the Middle and Northern Mining Districts; by Dr. John B. Trask, State Geologist. Senate Doc. No. 14. Sacramento, 1855. 95 pp.

This report contains a description of the physical geography of the coast mountains; geology of the coast mountains; Tertiary rocks of the coast mountains; primitive rocks of the coast mountains; volcanic rocks of the coast mountains; geology of the San Bernardino Mountains; stratified rocks of the San Bernardino chain and plains of Los Angeles; extent of the infusorial group; plains of Los Angeles; artesian borings; soils and productions of Los Angeles; mineral pro-

ductions of Los Angeles; country north of the American River; mineral district of the upper Sacramento Valley; geology of the northern coast mountains; local geology of the northern coast mountains; Carboniferous limestone of the eastern part of Shasta County; Trinity County; structure of the Sacramento Valley; Tertiary rocks and other deposits of the Sierra Nevada; placer mining; quartz veins; quartz mines, with descriptions of mines, and statistics.

Report on the Geology of the Coast Mountains and part of the Sierra Nevada, embracing their industrial resources in agriculture and mining; by Dr. John B. Trask, State Geologist. Assembly Doc. No. 9, Session of 1854. 92 pp.

This report contains a description of the geology of the Monte Diablo range, Salinas Valley, from Point Pinos to the Nacimiento River, Santa Cruz Mountains; structure of the valleys of Sacramento and San Joaquin; review of the geological changes in the coast mountains and Monte Diablo range; classification of the rocks of the coast mountains and Monte Diablo range; position and relation of the volcanic rocks to the Tertiaries; volcanic rocks preceding the Tertiary era; most recent volcanic rocks of the coast mountains; changes of level and river terraces; soils of the valley Santa Clara and shores of the Bay of San Francisco; valley of the Salinas; soils of the Salinas; Pajaro Valley; Livermore Valley; mineral resources of the coast mountains; mineral districts, embracing parts of the counties of Nevada, Placer, El Dorado, and Calaveras; quartz veins, and their relative age in California; character and position of the older veins below the surface; present government of metallic veins; descriptions of mines, with list of gold mines.

Report on the Geology of Northern and Southern California, embracing the mineral and agricultural resources of those sections; with statistics of the Northern, Southern, and Middle mines; by Dr. John B. Trask. Assembly Doc. No. 14, Session of 1856. 66 pp.

This report contains a description of the physical geography lying in the coast mountains north of the Bay of San Francisco; geological structure of the coast mountains; mineral character of the primitive rocks of the coast mountains; soils of Petaluma County; plains west of the Sacramento River; San Bernardino; geology of Table Mountain, Tuolumne County; Carboniferous rocks of the Northern district; salines of the upper Sacramento Valley; Mammoth Mines Seventy-six, Jamison Creek; descriptions of mines, etc.; analysis of saline waters from Lick Springs, Shasta County; gold mines in operation in 1855; table of altitudes.

SURVEYOR-GENERAL REPORTS.

Geology of a part of Calaveras County. December, 1854. By William Patton. In Report to the Surveyor-General of California; Document No. 5, Appendix F, pp. 86–88. Sacramento, 1855.

The tract noticed embraces an extent of the county between the Moquelumne River and Middle Fork, and the Stanislaus and North Fork, longitudinally; and latitudinally, the space between the foothills and the headwaters of the San Antonio branch of the Calaveras.

Report of a survey of a portion of the eastern boundary of California, and a reconnoissance of the old Carson and Johnson immigrant roads over the Sierra Nevada. In Annual Report of the Surveyor-General, 1856; Assembly Document No. 5, Session of 1856, pp. 91–186.

This report, by George H. Goddard, contains a few geological notes on rocks along the route.

SECOND GEOLOGICAL SURVEY OF CALIFORNIA.

J. D. WHITNEY, State Geologist.

The Geological Survey of California. An address delivered before the Legislature of California, at Sacramento, Tuesday evening, March 12, 1861, by J. D. Whitney, State Geologist. To which is appended a copy of the Act authorizing the survey. San Francisco, 1861. 50 pp.

Letter of the State Geologist relative to the progress of the State Geological Survey, by J. D. Whitney. San Francisco, 1862. 7 pp.

Lecture on Geology, delivered before the Legislature of California, at San Francisco, Tuesday evening, February 27, 1862, by J. D. Whitney. San Francisco, 1862. 33 pp.

Lecture on Geology, delivered before the Legislature of California, at Sacramento, Tuesday evening, March 19, 1863, by J. D. Whitney. Sacramento, 1863. 17 pp.

Annual Report of the State Geologist of California for the year 1862. Sacramento, 1862. 12 pp.

Annual Report of the State Geologist for the year 1863. Sacramento, 1864. 7 pp.

Letter of the State Geologist, relative to the progress of the State Geological Survey during the years 1864–65, by J. D. Whitney. Sacramento, 1866. 14 pp.

Letter of the State Geologist, relative to the progress of the State Geological Survey during the years 1866–67, by J. D. Whitney. Sacramento, 1867. 15 pp.

An Address on the propriety of continuing the State Geological Survey of California, delivered before the Legislature, January, 1868, by J. D. Whitney. San Francisco, 1868. 23 pp.

Report of the State Geologist on the condition of the Geological Survey of California, by J. D. Whitney. Sacramento, 1869. 7 pp.

Letter of the State Geologist relative to the progress of the Geological Survey during the years 1870–71. Sacramento, 1871. 13 pp.

Statement of the progress of the State Geological Survey of California during the years 1872–73, by J. D. Whitney. Sacramento, 1873. 14 pp.

Report of the Joint Committee on the Geological Survey of the State, made to the Legislature in 1874.

Report of sub-committee of the Committee on Mines and Mining Interests of the Senate, concerning the State Geological Survey. Sacramento, 1866. 5 pp.

Mining Statistics, No. 1. Tabular statement of the condition of the auriferous quartz mines and mills in that part of Mariposa and Tuolumne Counties lying between the Merced and Stanislaus Rivers; by A. Rémond. April, 1866. 16 pp.

The Yosemite Book. A description of the Yosemite Valley and the adjacent regions of the Sierra Nevada and Big Trees of California. New York, 1868. pp. 4 to 116. 2 maps and 28 photographs. 4to. (250 copies printed.)

Another edition. Cambridge, 1870. viii and 155 pp., and 2 maps.

Another edition. Cambridge, 1871. vii and 133 pp., and 2 maps.

Another edition, revised and corrected. Cambridge, 1874. viii and 186 pp., and 4 maps.

Geographical catalogue of the Mollusca found west of the Rocky Mountains, between latitudes 33° and 49°; by J. G. Cooper. San Francisco, 1867. 40 pp.

This catalogue was based on that published by P. P. Carpenter, Brit. Assoc. Adv. Sci., 1863, with the addition of about 130 species.

Catalogue of the Invertebrate Fossils of the Western Slope of the United States, Part II; by J. G. Cooper. San Francisco, 1871. 39 pp.

This catalogue was intended merely as a check-list and for labels; supplementing the catalogue published in 1867.

The author gives a list of the Post Pliocene, Pliocene, and Miocene fossils described in detail in "Palæontology of California."

Palæontology, Vol. 1. Carboniferous and Jurassic fossils, by F. B. Meek. Triassic and Cretaceous fossils; by W. M. Gabb. Philadelphia, 1864. xx and 243 pp. 32 plates.

The following fossils are described and illustrated in this volume:

CARBONIFEROUS—

FORAMINIFERA — *Fusulina robusta*, Meek; *F. gracilis*, Meek; *F. cylindrica*, Fischer?

ZOÖPHYTA—*Lithostrotion mamillare ?*, Castlenau; *L. ? Californiense*, Meek; *L.* sp.?; *Clisiophyllum Gabbi*, Meek.

BRACHIOPODA—*Orthis* (sp. undt.); *Productus semireticulatus*, Martin; *Rhynchonella* (sp. undt.); *Spirifer lineatus*, Martin?; *Spiriferina* (sp. undt.); *Retzia compressa*, Meek.

GASTEROPODA—*Euomphalus Whitneyi*, Meek.

Triassic fossils of California and adjacent Territories; by W. M. Gabb.

Orthoceratites Blakei, n.sp.; *Nautilus Whitneyi*, n.sp.; *N. multicameratus*, n.sp.; *Goniatites lævidorsatus*, Hauer; *Ceratites Haidingeri*, Hauer; *C. Whitneyi*, n.sp.; *Ammonites Blakei*, n.sp.; *A. ausseanus*, Hauer; *A. Homfrayi*, n.sp.; *A. Billingsianus*, n.sp.; *A. Ramsaueri?*,

Quenst; *Myacites* (*Panopœa?*) *Humboldtensis*, n.sp.; *Panopœa? Rémondi; Corbula Blakei*, n.sp.; *Mytilus Homfrayi*, n.sp.; *Avicula Homfrayi*, n.sp.; *A. macronata*, n.sp.; *Halobia? dubia*, n.sp.; *Monotis subcircularis*, n.sp.; *Rhynchopterus*, n.gen.; *R. obesus*, n.sp.; *Posidonomya stella*, n.sp.; *P. Daytonensis*, n.sp.; *Myophoria alta*, n.sp.; *Pecten deformis*, n.sp.; *Terebratula Humboldtensis*, n.sp.; *Rhynchonella lingulata*, n.sp.; *R. æquiplicata*, n.sp.; *Spirifer Homfrayi*, n.sp.

Jurassic fossils; by F. B. Meek.

Rhynchonella gnathophora, Meek; *Terebratula* sp.?; *Gryphæa* sp.?; *Lima? sinuata*, Meek; *L. recticostata*, Meek; *L.? cuneata*, Meek; *Pecten acutiplicatus*, Meek; *Inoceramus? obliquus*, Meek; *I.? rectangulus*, Meek; *Trigonia pandicosta*, Meek; *Mytilus multistriatus*, Meek; *Astarte ventricosa*, Meek; *Unicardium? gibbosum*, Meek; *Myacites depressus*, Meek; *Belemnites* sp.?

Cretaceous fossils, by W. M. Gabb.

CRUSTACEA—*Callianassa Stimpsoni*, n.sp.

CEPHALOPODA—*Belemnites impressus*, n.sp.; *Nautilus Texanus?*, Shum.; *Aturia Mathewsoni*, n.sp.; *Ammonites subtricarinatus*, D'Orb; *A. Newberryanus*, Meek; *A. Breweri*, n.sp.; *A. Haydeni*, n.sp.; *A. Peruvianus*, DeBuch?; *A. Traski*, n.sp.; *A. ramosus*, Meek; *A. Hoffmani*, n.sp.; *A. Rémondi*, n.sp.; *A. Batesi*, Trask; *A. Chicoensis*, Trask; *A. complexus*, H. & M.?; *? A. Cooperi*, n.sp.; *Hamites Vancouverensis*, n.sp.?; *Helicoceras vermicularis*, n.sp.; *H. Breweri*, n.sp.; *H. declive*, n.sp.; *Turrilites* (sp. undt.); *Ptychoceras æquicostatus*, n.sp.; *P.* (*? Hamites*) *quadratus*, n.sp.; *Crioceras* (*Ancyloceras?*) *Rémondi*, n.sp.; *C. latus*, n.sp.; *C. percostatus*, n.sp.; *Ancyloceras* (sp. undt.); *Baculites Chicoenis*, Trask; *B.* (sp. undt.).

GASTEROPODA—*Typhis antiquus*, n.sp.; *Fusus Martinez*, n.sp.; *F. Matthewsoni*, n.sp.; *F. Averilli*, n.sp.; *F. diaboli*, n.sp.; *F. aratus*, n.sp.; *F. flexuosus*, n.sp.; *F. Kingi*, n.sp.; *F. Californicus*, Conrad; subgen. *Hemifusus; Fusus* (*Hemifusus*) *Horni; F.* (*H.*) *Cooperi*, n.sp.; *F.* (*H.*) *Rémondi*, n.sp.; cf. *Pyrula penita*, Conrad; *Neptunea curvirostris*, n.sp.; *N. ponderosa*, n.sp.; *N. perforata; ? N. supraplicata*, n.sp.; *N. Hoffmani*, n.sp.; *N. gracilis*, n.sp.; *Perissolax brevirostris*, n.sp.; *P. Blakei*, Conrad; *Turris Claytonensis*, n.sp.; *T.* (sub.gen. *Drillia*) *varicostata*, n.sp.; *Cordiera microptygma*, n.sp.; *Tritonium Horni*, n.sp.; *T. Diegoensis*, n.sp.; *T. paucivaricatum*, n.sp.; *Cancellaria* (Heilprin, Ter. Geol., p. 113; badly figured); *T. Whitneyi*, n.sp.; *Buccinum liratum*, n.sp.; *Nassa cretacea*, n.sp.; *N. antiquata*, n.sp.; *Haydenia*, n.gen.; *H. impressa*, n.sp.; *Pseudoliva lineata*, n.sp.; *P. volutæformis*, n.sp.; *Olivella Mathewsoni*, n.sp.; *Ancillaria elongata*, n.sp.; *? Fasciolaria læviuscula*, n.sp.; *F. sinuata*, n.sp.; *? F. Io.*, n.sp.; *Volutilithes Navarroensis*, Shum.; *Mitra cretacea*, n.sp.; *Whitneya*, n.gen.; *W. ficus*, n.sp.; *Morio* (sub.gen. *Sconsia*); *M. tuberculatus*, n.sp.; *Ficus?; F. cypræoides*, n.sp.; *Lunatia avellana*, n.sp.; *L. Shumardiana*, n.sp.; *L. Horni*, n.sp.; *L. nuciformis*, n.sp.?; *L.* (*Gyrodes?*) *Conradiana*, n.sp.; *Gyrodes expansa*, n.sp.; *Neverita secta*, n.sp.; *Naticina obliqua*, n.sp.; (*Sigaretus*, Heilprin Ter. Geol., p. 113); *Amauropsis oviformis*, n.sp.; *A. alveata*, n.sp.; *Cinulia obliqua*, n.sp.; *C. Mathewsoni*, n.sp.; *C. pinguis*, n.sp.; *Ringicula varia*, n.sp.; *Nerinea dispar*, n.sp.; *Acteonina ? pupoides*, n.sp.; *A. Californica*, n.sp.; *Globi-*

***concha* (*Phasianella?*) *Rémondi*, n.sp.; *Cylindrites brevis*, n.sp.; *Chemnitzia Spillmani*, Conrad; *Niso polita*, n.sp.; *Cerithiopsis alternata; Architectonica Veatchi*, n.sp.; *A. cognata*, n.sp.; *A. Horni*, n.sp.; *A. inornata*, n.sp.; *Margaritella crenulata*, n.sp.; *M. globosa*, n.sp.; *Discohelix leana*, n.sp.; *Straparollus paucivolus*, n.sp.; *S. lens*, n.sp.; *Angaria ornatissima*, n.sp.; *Conus Rémondi* (*Volutilithes Californica*, Conrad); *C. Horni*, n.sp.; *C. sinuatus*, n.sp.; *Rostellaria* (sub.gen. *Rimella*); *R. canalifera*, n.sp.; *R.* (*Rimella*) *simplex*, n.sp.; *Pugnellus hamulus*, n.sp.; *P. manubriatus*, n.sp.; *Tessarolax*, n.gen.; *T. distorta*, n.sp.; *Aporrhais falciformis*, n.sp.; *A. angulata*, n.sp.; *A. Californica*, n.sp.; *A. exilis*, n.sp.; *Cypræa? Bayerquei*, n.sp.; *Potamides diadema*, n.sp.; *P. tenuis*, n.sp.; *Littorina? compacta*, n.sp.; *Turritella infralineata*, n.sp.; *T. seriatim-granulata*, Rœmer; *T. Veatchi*, n.sp.; *T. Chicoensis*, n.sp.; *T. Uvasana*, Conrad; *T. Saffordi*, Gabb; *T. robusta*, n.sp.; *Galerus excentricus*, n.sp.; *Crypta* (sub.gen. *Spirocrypta*); *C. pileum*, n.sp.; *Nerita deformis*, n.sp.; *N. cuneata*, n.sp.; *Lysis*, n.gen.; *L. duplicosta*, n.sp.; *Dentalium* (*Ditrupa?*) *pusillum*, n.sp.; *D. Cooperi*, n.sp.; *D. stramineum*, n.sp; *Emarginula radiata*, n.sp.; *Patella Traski*, n.sp.; *Helcion? circularis*, n.sp.; *H. dichotoma*, n.sp.; *Anisomyon Meeki*, n.sp.; *Actæon impressus*, n.sp.; *Bulla Horni*, n.sp.; *Cylichna costata*, n.sp.; *Megistostoma*, n.gen.; *M. striata*, n.sp. (Heilprin, Ter. Geol., p. 113, refers this to *Bullæa* cf. *Bullæa expansa*, Dixson).

CONCHIFERA—*Martesia clausa*, n.sp.; *Turnus*, n.gen.; *T. plenus*, n.sp.; *Solen parallelus*, n.sp.; *Pharella alta*, n.sp.; *Siliqua Oregonensis*, n.sp.; *Panopæa concentrica*, n.sp.; *Corbula? primorsa*, n.sp.; *C. Traski*, n.sp.; *C. cultriformis*, n.sp.; *C. Horni*, n.sp.; *C. parilis*, n.sp.; *Anatina Tryoniana*, n.sp.; *A. inæquilateralis*, n.sp.; *A.? lata*, n.sp.; *Pholadomya Breweri*, n.sp.; *P. nasuta*, n.sp.; *Neæra dolabræformis*, n.sp.; *Mactra Ashburneri*, n.sp.; *Lutraria truncata*, n.sp.; *Asaphis undulata*, n.sp.; *Gari? texta*, n.sp.; *Tellina longa*, n.sp.; *T. Rémondi*, n.sp.; *T. Hoffmanniana*, n.sp.; *T. monilifera*, n.sp.; *T. ooides*, n.sp.; *T. Mathewsoni*, n.sp.; *T. decurtata*, n.sp.; *T.? quadrata*, n.sp.; *T. Ashburneri*, n.sp.; *T.* (*? Sanguinolaria*) *Whitneyi*, n.sp.; *T. parilis*, n.sp.; *T. Horni*, n.sp.; *T. Californica*, n.sp.; *Venus* (*Mercenaria?*) *varians*, n.sp.; *V. Veatchi*, n.sp.; *V. lenticularis*, n.sp.; *V. tetrahedra*, n.sp.; *Meretrix Uvasana*, Conrad; *M. lens*, n.sp.; *M. Horni*, n.sp.; *M. nitida*, n.sp.; *M. longa*, n.sp.; *M. arata*, n.sp.; *M. ovalis*, n.sp.; *M. Californica*, Conrad; *Dosinia elevata*, Gabb (Heilprin, Ter. Geol., p. 115, refers this to *Disiniopsis Meeki*, Conrad); *D. pertenuis*, n.sp.; *D. gyrata*, n.sp.; *D. inflata*, n.sp.; *Tapes Conradiana*, n.sp.; *T.? quadrata*, n.sp.; *Trapezium carinatum*, n.sp.; *Cyprinella*, n.gen.; *C. tenuis*, n.sp.; *Cardium* (*Lævicardium*) *annulatum*, n.sp.; *C. Rémondianum*, n.sp.; *C. Cooperi*, n.sp.; *C. Breweri*, n.sp.; *C.* (*Protocardium*) *Placerensis*, n.sp.; *Cardita Horni*, n.sp.; *Lucina nasuta*, n.sp.; *L. postradiata*, n.sp.; *L. subcircularis*, n.sp.; *L. cumulata*, n.sp.; *L.? cretacea*, n.sp.; *Loripes? dubia*, n.sp.; *Mysia ? polita*, n.sp.; *Astarte Conradiana*, n.sp.; *A. Mathewsoni*, n.sp.; *A. Tuscana*, n.sp.; *Eriphyla*, n.gen.; *E. umbonata*, n.sp.; *Crassatella grandis*, n.sp.; *Anthonya*, n.gen.; *A. cultriformis*, n.sp.; *Unio penultimus*, n.sp.; *Mytilus pauperculus*, n.sp.; *M. ascia*, n.sp.; *M. humerus*, Conrad; *Modiola Siskiyouensis*, n.sp.; *M. ornata*, n.sp.; *M. cylindrica*, n.sp.; *Lithophagus oviformis*, n.sp.; *Septifer dichotomus*, n.sp.; *Crenella concentrica*, n.sp.; *Avicula pellucida*, n.sp.; *Inoceramus Piochi*, n.sp.; *Pinna Breweri*, n.sp.; *Trigonia Tryoniana*,

n.sp.; *T. Evansi*, Meek; *T. Gibboniana*, Lea?; *Meekia*, n.gen.; *M. Sella*, n.sp. (there is already a genus named *Meekella*, after Meek, so this will not stand); *M. radiata*, n.sp.; *M. navis*, n.sp.; *Arca Breweriana*, n.sp.; *A. Horni*, n.sp.; *A. gravida*, n.sp.; *A. decurtata*, n.sp.; *Cucullæa Mathewsoni*, n.sp.; *C. truncata*, n.sp.; *Axinæa Veatchi*, n.sp.; *A. (Limopsis?) sagittata*, n.sp.; *A. cor*, n.sp.; *Nucula truncata*, n.sp.; *Leda protexta?*, Gabb; *L. translucida*, n.sp.; *Limopsis transversa*, n.sp.; *Pecten Traski*, n.sp.; *P. operculiformis*, n.sp.; *P. Californicus*, n.sp.; *Lima microtis*, n.sp.; *L. appressa*, n.sp.; *Plicatula variata*, n.sp.; *Anomia lineata*, n.sp.; *Ostrea Breweri*, n.sp.; *O. malleiformis*, n.sp.; *Gryphæa vesicularis*, Lam.; *Exogyra parasitica*, n.sp.; *Terebratella obesa*, n.sp.

ZOÖPHYTA—*Flabellum Rémondianum*, n.sp.; *Trochosmilia* (subgen. *Acrosmilia*); *T. striata*, n.sp.; subgen. *Ellipsosmilia? granulifera*, n.sp.; *Astrocœnia? petrosa*, n.sp.

The Appendix contains descriptions of the following fossils:

Fusus mamillatus, n.sp.; *Natica Uvasana*, n.sp.; *Scalaria Mathewsoni*, n.sp.; *Turritella infra-granulata*, n.sp.; *Solen Diegoensis*, n.sp.; *Chione? angulata*, n.sp.; *Tapes? cretacea*, n.sp.; *Crassatella Uvasana*, Conrad; *Cardita veneriformis*, n.sp.; *Barbatia Morsei*, n.sp.; *Yoldia nasuta*, n.sp.; *Placunanomia inornata*, n.sp.

Palæontology, Vol. 2. Cretaceous and Tertiary fossils, by W. M. Gabb. Philadelphia, 1869. xiv and 299 pp., with 36 plates.

Section I. Tertiary invertebrate fossils:

Cancer Breweri, n.sp.; *Triptera clavata*, n.sp.; *Trophon ponderosum*, n.sp.; *Neptunea recurva*, n.sp.; *Metula? Rémondi*, n.sp.; *Clavella gravida*; n.sp.; *C. sinuata*, n.sp.; *Pleurotoma* (*Surcula*) *Carpenteriana*, Gabb; *P.* (*S.*) *Tryoniana*, n.sp.; *P.* (*S.*) *perversa*, Gabb; *P. Voyi*, n.sp.; *Clathurella Conradiana*, n.sp.; *Ranella Mathewsoni*, n.sp.; *Cuma biplicata*, n.sp.; *Ancillaria Fishi*, n.sp.; *Columbella* (subgen. *Alia*) *Richthofeni*, n.sp.; *Neverita callosa*, n.sp.; *Cancellaria* (subgen. *Euclia*) *Tritonidea*, n.sp.; *C.* (*E.*) *vetusta*, n.sp.; *Bittium asperum*, Gabb; *Melania Taylori*, n.sp.; *Lithasia antiqua*, n.sp; *Littorina Rémondi*, n.sp.; *Turritella Hoffmanni*, n.sp.; *Trochita filosa*, n.sp.; *Pachypoma? biangulata*, n.sp.; *Turcica* (subgen. *Ptychostylis*) *coffea*, Gabb; *Calliostoma tricolor*, Gabb; *Zirphæa dentata*, n.sp.; *Pandora scapha*, n.sp.; *Hemimactra lenticularis*, n.sp.; *Mulinia? densata*, Conrad pars.; *Schizodesma abscissa*, n.sp.; *Pseudocardium*, n.gen.; *P. Gabbi*, Rémond; *Gari* (subgen. *Psammocola*) *alata*, n.sp.; *Venus Kennerlyi*, Rve.? *Mercenaria perlaminosa*, Conrad; *Chione Mathewsoni*, n.sp.; *C. Whitneyi*, n.sp.; *Callista Voyi*, n.sp.; *Dosinia Staleyi*, n.sp.; *D. Conradi*, n.sp.; *Tapes? truncata*, n.sp.; *Cyrena Californica*, n.sp.; *Cardium Meekianum*, n.sp.; *Conchocele*, n.gen.; *C. disjuncta*, n.sp.; *Lucina* (subgen. *Here*); *L.* (*H.*) *Richthofeni*, n.sp.; *Crassatella Collina*, Conrad; *Mytilus Mathewsoni*, n.sp.; *Modiola multiradiata*, n.sp.; *Arca sulcicosta*, n.sp.; *Yoldia Cooperi*, Gabb; *Pecten Cerrosensis*, n.sp.; *P. Veatchi*, n.sp.; *Ostrea Bourgeoisi*, Rémond; *O. Atwoodi*, n.sp.; *O. Tayloriana*,

n.sp.; *O. Veatchi*, n.sp.; *O. Cerrosensis*, n.sp.; *Terebratella Whitneyi*, n.sp.; *Morrisia Horni*, Gabb.

ECHINODERMATA — *Clypeaster Gabbi*, Rémond; *Echinarachinus Brewerianus*, Rémond; *Scutella Gibbsi*, Rémond; *Astrodapsis Whitneyi*, Rémond; *A. tumidus*, Rémond.

ASTERIADÆ—*Asterias Rémondi*, n.sp.

Part 2.

Muricidea (? *Phyllonotus*) *paucivaricata*, n.sp.; *Trophon squamulifer*, Cpr. (in lit.), n.sp.; *Neptunea allispira*, n.sp.; *N. humerosa*, n.sp.; *Agasoma*, n.gen.; *A. gravida*, Gabb; *A. sinuata*, Gabb; *Surcula Tryoniana*, Gabb: *Nassa* (sub.gen. *Cæsia*); *Ficus pyriformis*, n.sp.; *F. nodiferus*, n.sp.; *Sinum planicostum*, n.sp.; *Cancellaria gracilior*, Cpr. (in lit.), n.sp.; *C. altispira*, n.sp.; *Trochita inornarta*, n.sp.; *Acmæa rudis*, n.sp.; *Zirphæa Gabbi*, Tryon; *Siliquaria? Edentula*, n.sp.; *Clidophora punctata*, Conrad; *Hemimactra? occidentalis*, n.sp.; *Pseudocardium* (remarks on the genus); *Venus pertenuis*, Gabb; *Caryatis Barbarensis*, n.sp.; *Meretrix Traski*, Conrad; *Dosinia Mathewsoni*, n.sp.; *Tapes Staleyi*, Gabb; *Saxidomus gibbosus*, n.sp.; *Yoldia nasuta*, Gabb; *Y. impressa*, Conrad; *Pecten Peckhami*, n.sp.; *P. Pedroanus*, Trask; *Ostrea Veatchi*, Gabb; *Tamiosoma gregaria*, Conrad.

Part 3 contains a synopsis of the Tertiary invertebrate fossils of California.

Section II. Cretaceous fossils, Part 1, continued from Vol. 1.

CRUSTACEA—*Callianassa Stimpsoni*, Gabb.

MOLLUSCA—*Ptiloteuthis*, n.gen.; *P. foliatus*, n.sp.; *Belemnites impressus*, Gabb; *Ammonites Breweri*, Gabb; *A. Traski*, Gabb; *A. Hoffmanni*, Gabb; *A. Batesi*, Trask; *A. Tehamaensis*, Gabb; *A. Suciaensis*, Meek; *A. Jugalis*, n.sp.; *A. Whitneyi*, n.sp.; *A. Stoliczkanus*, n.sp.; *A. fraternus*, n.sp.; *Turrilites Oregonensis*, Gabb; *Ancyloceras Rémondi*, Gabb; *A. percostatus*, Gabb; *A.? lineatus*, n.sp.; *Helicancylus*, n.gen.; *H. æquicostatus*, Gabb; *Diptychoceras*, n.gen.; *D. lævis*, n.sp.; *Baculites occidentalis*, Meek.

GASTEROPODA—*Fusus tumidus*, n.sp.; *F. occidentalis*, n.sp.; *Neptunea* (*Tritonofusus*) *cretacea*, n.sp.; *N. mucronata*, n.sp.; *Palæa tractus*, n.gen.; *P. crassus*, n.sp.; *Eripachya*, n.gen.; *E. ponderosa*, Gabb; *E. perforata*, Gabb; *E. Hoffmanni*, Gabb; *? Neptunea gracilis*, Gabb; *Perissolax Blakei*, Conrad; *Surcula præattenuata* n.sp.; *S.* (*Surculites*) *sinuata*, Gabb; *S.* (*Surculites*) *inconspicus*, n.sp.; *Heteroterma*, n.gen.; *H. trochoidea*, n.sp.; *Bela clathrata*, n.sp.; *Cordiera mitræformis*, n.sp.; *Tritonium Californicum*, n.sp.; *T.* (subgen. *Trachytriton*) *Tejonensis*, n.sp.; *T.* (*T.*) *fusiformis*, n.sp.; *Brachysphingus*, n.gen.; *B. liratus*, Gabb; *Bulla* (*Molopophorus*) *striata*, n.sp.; *Turbinella crassitesta*, n.sp.; *Mitra cretacea*, Gabb; *Ficopsis Rémondi*, Gabb; *F. Horni*, Gabb; *F. Cooperi*, Gabb; *Urosyca*, n.gen.; *U. caudata*, n.sp.; *Sycodes*, n.gen.; *S. cypræoides*, Gabb; *Euspira alveata*, Conrad; *Neverita globosa*, n.sp.; *Ampullina striata*, n.sp.; *Terebra Californica*, n.sp.; *Chemnitzia planulata*, Gabb; *Pugnellus hamulus*, Gabb; *P.* (*Gymnarus*) *manubriatus*, Gabb; *Cypræa* (*Luponia*) *Bayerquei*, Gabb; *C.* (*Epona*) *Mathewsonia*, n.sp.; *Anchura*

falciformis, Gabb; *A. transversa*, n.sp.; *?A. carinifera*, n.sp.; *Helicaulax bicarinata*, n.sp.; *H. costata*, n.sp.; *Loxotrema turrita*, n.sp.; *Atresius*, n.gen.; *A. liratus*, n.sp.; *Turritella Martinezensis*, n.sp.; *Nerita* (*Theliostyla*) *triangulata*, n.sp.; *Calliostoma radiatum*, n.sp.; *Ataphrus*, n.gen.; *A. crassus*, n.sp.; *Margaritella angulata*, n.sp.; *Acmæa Tejonensis*, n.sp.; *Actæonina pupoides*, Gabb; *Actæonella oviformis*, n.sp.; *Liocium*, n.gen.; *L. punctatum*, n.sp.; *Ringinella polita*, n.sp.; *R. pinguis*, Gabb.

ACEPHALA—*Martesia clausa*, Gabb; *Solen* (*Hypogella*) *cuneatus*, n.sp.; *S.* (*H.*) *Diegoensis*, Gabb; *Corbula Horni*, Gabb; *C. alæformis*, n.sp.; *Anatina quadrata*, n.sp.; *Pholadomya Oregonensis*, n.sp.; *Pleuromya papyracea*, n.sp.; *Arcomya undulata*, n.sp.; *Homomya concentrica*, Gabb; *Mactra? tenuissima*, n.sp.; *Cymbophora*, n.gen.; *C. Ashburneri*, Gabb; *Asaphis multicostata*, n.sp.; *Tellina Rémondi*, Gabb; *T. Hoffmanni*, Gabb; *T. æqualis*, n.sp.; *T. undulifera*, n.sp.; *Donax latus*, n.sp.; *Venus æquilateralis*, n.sp.; *Meretrix? fragilis*, n.sp.; *M. Horni*, Gabb; *Caryatis nitida*, Gabb; *Thetis? elongata*, n.sp.; *Cardium* (*Lævicardium*) *annulatum*, Gabb; *C.* (*Protocardium*) *translucidum*, n.sp.; *Cardita Horni*, Gabb; *Clisocolus*, n.gen.; *C. dubius*, Gabb; *Lucina nasuta* and *L. postice-radiata; Crassatella grandis*, Gabb; *C. compacta*, n.sp.; *Unio Hubbardi*, n.sp.; *Mytilus quadratus*, n.sp.; *Modiola major*, n.sp.; *Meleagrina antiqua*, n.sp.; *Inoceramus Elliotti*, n.sp.; *I. Whitneyi*, n.sp.; *Aucella Piochi*, Gabb; *Pinna Breweri*, Gabb; *Trigonia æquicostata*, n.sp.; *Axinæa sagittata*, Gabb; *Nucula* (*Acila*) *truncata*, Gabb; *N. solitaria*, n.sp.; *Leda Gabbi*, Conrad; *Pecten Traski*, Gabb; *P. Martinezensis*, n.sp.; *P. complexicosta*, n.sp.; *P. interradiatus*, n.sp.; *Neithea grandicosta*, n.sp.; *Lima Shastaensis*, n.sp.; *L. multiradiata*, n.sp.; *Anomia Vancouverensis*, n.sp.; *Ostrea Idriaensis*, n.sp.; *O. appressa* n.sp.; (*O. Idriaensis* (Gabb), White, 4th Ann. Rep. U. S. Geol. Sur., p. 291.)

BRACHIOPODA—*Rynchonella Whitneyi*, Gabb.

RADIATA—*Smilotrochus? curtus*, n.sp.

Part 2 contains a synopsis of the Cretaceous invertebrate fossils of California.

Section III contains description of the Cretaceous fossils from Mexico; by W. M. Gabb.

Geology, Vol. 1. Report of progress and synopsis of the field-work from 1860 to 1864. Philadelphia, 1865. xxxii and 498 pp., and plate.

Part 1 of this report contains: Geology of the Coast Range, Contra Costa hills, Monte Diablo group, Mount Hamilton group, Monte Diablo group, south of Pacheco's Pass; the Peninsula of San Francisco; the coast ranges north of the Bay of San Francisco; the coast ranges south of the Bay of Monterey; the coast ranges from the vicinity of Los Angeles south; the region between the Cañada de las Uvas and Soledad Pass.

Part 2. The geology of the Sierra Nevada; the undisturbed marine sedimentary rocks along the foothills of the Sierra; the mining regions of California, embracing the great auriferous belt along the

western slope of the Sierra Nevada; the high Sierra region about the head of Kern, Kings, San Joaquin, Merced, Tuolumne, and Mokelumne rivers; the eastern slope—Mono Lake and its vicinity, Owen's Valley, the Great Basin, etc.

Appendix A. Tabular statement of the operations of the principal quartz mills; by W. Ashburner.

Appendix B. Description of fossils from the auriferious slates of California; by F. B. Meek.

The following fossils are described and illustrated in this report: *Amussium aurarium*, Meek; *Aucella Erringtoni*, Gabb; *A. Erringtoni* var. *lingulifromis; Pholadomya? orbiculata*, Gabb; and *Belemnites Pacificus*, Gabb.

Contributions to barometric hypsometry, with tables for use in California. Cambridge, 1874. 88 pp. (Supplementary chapter added in 1878; pp. 89–112.)

Supplementary chapter, and practical application of the tables to the observations of the year 1870–71, and a discussion of the results obtained; by J. D. Whitney. Cambridge, 1878. 24 pp.

Botany, Vol. 1. Polypetalæ, by W. H. Brewer and Sereno Watson. Gamopetalæ, by Asa Gray. Cambridge, 1876. xx and 628 pp.

Ornithology, Vol. 1. Land-birds; edited by S. F. Baird from the manuscript and notes of J. G. Cooper. Cambridge, 1870. xi and 592 pp.

Map of region adjacent to the Bay of San Francisco. 2 miles to 1 inch. New York, 1873.

Map of California and Nevada. 1873. State Geological Survey of California; J. D. Whitney, State Geologist. Drawn by F. von Leicht and A. Craven. Scale, 18 miles to 1 inch.

Same, 2d edition. Revised by Hoffmann & Crane, and issued by authority of the Regents of the University of California, May 12, 1874. Same scale.

Same, 3d edition. Published by W. D. Walkup & Co. San Francisco, 1878. Same scale.

A new edition by W. D. Walkup & Co. 1887.

The following volumes and memoirs are to be credited to the Geological Survey of California, J. D. Whitney, Director, as a

continuation, in part, of the work stopped by the Legislature in 1874; permission having been given to the late State Geologist, by the Board of Regents of the University of California, in whose hands the matter was left, to continue the publications:

Geology, Vol. 2. The Coast Ranges. Appendix. Cambridge, 1882. 148 pp. 5 plates. (Uniform with publications of the Geological Survey of California, J. D. Whitney, State Geologist.)

This report contains—

A. Detailed description of the Monte Diablo coal fields; by W. A. Goodyear. April, 1870.

B. Additional notes on the Monte Diablo coal mines; by W. A. Goodyear. June, 1873.

C. Statistics of the Monte Diablo coal mines; by W. A. Goodyear. January, 1874.

D. Notes descriptive of the condition of the Corral Hollow coal mines; by W. A. Goodyear. August, 1870.

E. Chemical examination of the Pacific coals; by S. F. Peckham. I, July, 1872; II, September, 1872.

F. Examination of the Bituminous Substances in Southern California; by S. F. Peckham. Part I, Geological and Historical (June, 1866). Part II, Chemical Investigations: Section 1, February, 1867; Section 2, January, 1871.

G. Report on an examination of the Quicksilver Mines of California; by W. A. Goodyear. May, 1871.

H. Notes on the Geology of Lower California; by W. M. Gabb.

Botany, Vol. 2; by Sereno Watson. Cambridge, 1880. xv and 559 pp.

The water-birds of North America; by S. F. Baird, T. M. Brewer, and R. Ridgeway. Issued in continuation of the publications of the Geological Survey of California. Boston, 1884. Vol. 1, xi and 537 pp.; Vol. 2, 552 pp.

Report on the fossil plants of the auriferous gravel deposits of the Sierra Nevada; by Leo Lesquereux. Cambridge, 1878. viii and 62 pp., with 10 double plates.

Memoirs of the Museum of Comparative Zoölogy. Vol. VI, No. 2.

This report contains descriptions of the following fossil plants: *Acer æquidentatum*, n.sp.; *A. Bolanderi*, n.sp.; *Aralia angustiloba*, n.sp.; *A. Whitneyi*, n.sp.; *A. Zaddachi?* Heer; *Betula æqualis*, n.sp.; *Cercocarpus antiquus*, n.sp.; *Castaneopsis chrysophylloides*, n.sp.; *Cornus Kelloggi*, n.sp.; *C. ovalis*, n.sp.; *Fagus antipofi*, n.sp.; *F. pseudo-ferruginea*,

n.sp.; *Ficus microphylla*, n.sp.; *F. sordida*, n.sp.; *F. tiliæfolia*, Al. Br.; *Ilex prunifolia*, n.sp.; *Juglans Californica*, n.sp.; *J. Oregoniana*, n.sp.; *J. laurinea*, n.sp.; *Liquidambar Californicum*, n.sp.; *Magnolia Californica*, n.sp.; *M. lanceolata*, n.sp.; *Platanus appendiculata*, n.sp.; *P. dissecta*, n.sp.; *Populus Zaddachi*, Heer; *Persea pseudo-carolinensis*, n.sp. *Quercus Boweniana*, n.sp.; *Q. chrysophylloides*, n.sp.; *Q. convexa*, n.sp., *Q. distincta*, n.sp.; *Q. elænoides*, n.sp.; *Q. Goepperti*, n.sp.; *Q. Nevadensis*, n.sp.; *Q. pseudo-lyrata*, n.sp.; *Q. Voyana*, n.sp.; *Rhus Boweniana*, n.sp.; *R. dispersa*, n.sp.; *R. metopioides*, n.sp.; *R. mixta*, n.sp.; *R. myricæfolia*, n.sp.; *R. typhinoides*, n.sp.; *Sabalites Californicus*, n.sp.; *Salix Californica*, n.sp.; *S. elliptica*, n.sp.; *Ulmus affinis*, n.sp.; *U. Californica*, n.sp.; *U. pseudo-fulva*, n.sp.; *Zanthoxylon diversifolium*, n.sp.; *Zizyphus microphyllus*, n.sp.; *Z. piperoides*, n.sp.

The auriferous gravels of the Sierra Nevada of California; by J. D. Whitney. Cambridge, 1879–80, pp. 1–288; pp. 289–569, 1880. 24 plates and 2 geological maps.

The climatic changes of later geological times. A discussion based on observations made in the Cordilleras of North America. By J. D. Whitney. Cambridge, 1880–82. 394 pp.

CALIFORNIA STATE MINING BUREAU.

HENRY G. HANKS, State Mineralogist.

Annual Report of the State Mineralogist, from June 1, 1880, to December 1, 1880. Sacramento, 1880. 43 pp.

This report contains analysis of clay from a deposit at Lincoln, Placer County.

Second Report of the State Mineralogist, from December 1, 1880, to October 1, 1882. Sacramento, 1882. 288 pp., map and 4 photographs, with appendix. (The index to this report was published separately.)

The report contains articles on placer, hydraulic, and drift mining; general geology; iron ores and iron industries of California; lumber and fuel; the occurrence of salt in California, and its manufacture; mud volcanoes; the Colorado Desert; diamonds in California; notes on mica; diatoms and diatomaceous earths; contribution to ethnology and geology of the Pacific Slope, by Philip Harvey.

The appendix contains the following papers: 1. Forest trees of California, by A. Kellogg; 2. Notes on hydraulic mining, by F. W. Robinson; 3. Hydraulic and drift mining, by H. Degroot; 4. On the milling of gold quartz, by M. Attwood; 5. Rare minerals recently found in the State, by William P. Blake.

Contributions to the Geology and Mineralogy of California; by William P. Blake. Sacramento, 1881. 15 pp.

This report contains a description of new mineral localities.
No. 2. Section from Merced to Coulterville and Big Oak Flat.
No. 3. Coulterville to Chinese Camp.
No. 4. Chinese Camp to Sonora.
No. 5. Occurrence of vanadates of lead at the Castle Dome mines.

Contributions to the Geology and Mineralogy of California: On the milling of gold quartz; by Melville Attwood. Sacramento, 1882. 20 pp.

First Annual Catalogue of the State Museum of California, being the collection made by the State Mining Bureau during the year ending April 16, 1881. Sacramento, 1882. 350 pages.

Third Annual Report of the State Mineralogist, for the year ending June, 1883. Sacramento, 1883. 111 pp. and 1 map.

Part 2 contains a report on the borax deposits of California and Nevada, by Henry G. Hanks.

Fourth Annual Report of the State Mineralogist, for the year ending May 15, 1884. Sacramento, 1884. 410 pp. and 2 plates.

This volume contains a general account of the agricultural, commercial, manufacturing, and other resources, interests, and industries of California, by Henry Degroot.

Also, a catalogue and description of the minerals of California as far as known, with special reference to those having an economic value. Alphabetically arranged.

Fifth Annual Report of the State Mineralogist, for the year ending May 15, 1885. Sacramento, 1885. 235 pp., 1 plate and 4 sections.

Sixth Annual Report of the State Mineralogist, for the year ending June 1, 1886. Part I. Sacramento, 1886. 145 pp. and 1 map.

This report contains an article on building-stones and building-materials in California; table of altitudes; record of strata in artesian well, Kern County; mineral springs in California; Calistoga silver mines; a general account of San Diego County, with map of Julian District. The report closes with a list of California minerals.

Catalogue of books, maps, lithographs, photographs, etc., in the library of the State Mining Bureau at San Francisco, May 15, 1884. Sacramento, 1884. 19 pp.

Catalogue of the State Museum of California, Vol. 2, being the collection made by the State Mining Bureau from April 16, 1881, to May 15, 1884. Sacramento, 1885. 220 pp.

WILLIAM IRELAN, Jr., State Mineralogist.

Sixth Annual Report of the State Mineralogist, for the year ending June 1, 1886. Part II. Sacramento, 1887. 222 pp. Illustrated.

Contains reports on the mines of Amador, Butte, Calaveras, El Dorado, Fresno, Nevada, Sierra, and Tuolumne Counties.

Catalogue of the State Museum of California, Vol. 3, being the collection made by the State Mining Bureau from May 15, 1884, to March 31, 1887. Sacramento, 1887. 195 pp.

Seventh Annual Report of the State Mineralogist, for the year ending October 1, 1887. Sacramento, 1888. 315 pp.

This report contains an article on petroleum, asphaltum, and natural gas of California, by W. A. Goodyear; also, a report on coal, with reports on natural gas and coal in California, by A. H. Weber; petroleum and asphaltum in portions of Northern California, by A. H. Weber; building-stones of California, by Prof. A. Wendell Jackson; production of precious metals, report of Wells, Fargo & Co.; with a catalogue of fossils, by J. G. Cooper.

Eighth Annual Report of the State Mineralogist, for the year ending October 1, 1888. Sacramento, 1888. 948 pp. Illustrated.

This report contains the mineral resources of the State, considered by counties, with reports on natural and artificial cement, building-stones, etc.; reports on Inyo, Kern, Los Angeles, San Bernardino, San Diego, and Tulare Counties, by W. A. Goodyear; Mono County, by H. A. Whiting; Ventura County, by S. Bowers; drift mining in California, by R. L. Dunn; lithology of wall rocks, by M. Attwood.

Bulletin No. 1. A description of the desiccated human remains in the California State Mining Bureau; by Winslow Anderson, M.D. Sacramento, 1888. 41 pp. and 6 plates.

Ninth Annual Report of the State Mineralogist, for the year ending December 1, 1889. Sacramento, 1890. 352 pp. and 34 plates.

This report contains an article on Santa Clara County, by A. H. Weber; the geology of San Nicolas Island, by Dr. Stephen Bowers; the auriferous gravels of California, geology of their occurrence and methods of their exploitation, by John Hays Hammond; San Diego County, by W. A. Goodyear; Santa Cruz Island, by W. A. Goodyear; stray notes on the geology of the channel islands, by Dr. L. G. Yates; the mollusca of the channel islands of California, by Dr. L. G. Yates; with reports on Los Angeles County, by E. B. Preston, and San Bernardino County, by James H. Crossman; the value of fossils as indications of important mineral products, by Dr. J. G. Cooper; with report on clays, by W. D. Johnston; etc.

Tenth Annual Report of the State Mineralogist, for the year ending December 1, 1890. Sacramento, 1890. 981 pp. Maps and plates.

This report contains a geological map of the State, with the following special reports relating to geology, viz.:

Geology of the Mother Lode region; by H. W. Fairbanks.

Geological features of Placer County. pp. 414–418.

Geology of Nevada County. p. 368.

Geology of the Colorado Desert. pp. 907–919.

Geology of Trinity County. p. 695.

Geology of Orange County. pp. 399–409.

Fossils of the Carboniferous period. p. 917.

Fossils of Orange County. pp. 407–408.

List of Cretaceous fossils in Santa Ana Mountains, Orange County. p. 400.

Fossils of Ventura County. p. 762.

With other reports containing geological information.

Catalogue of the State Museum of California, Vol. 4, being the collection made by the State Mining Bureau from March 31, 1887, to August 20, 1890. Sacramento, 1890. 261 pp.

Catalogue of the Library of the California State Mining Bureau, San Francisco, September 1, 1892. Sacramento, 1892. 149 pp.

Eleventh Report (First Biennial) of the State Mineralogist, for the two years ending September 15, 1892. Sacramento, 1893. 612 pp.

This report contains the following special articles on geology, viz.:

Geology and mineralogy of Shasta County; by H. W. Fairbanks. pp. 24–53.

Notes on the geology and mineralogy of portions of Tehama, Colusa, Lake, and Napa Counties; by H. W. Fairbanks. pp. 54–75.

Geology of San Diego County, also of portions of Orange and San Bernardino Counties; by H. W. Fairbanks. pp. 76–120.

Geology of Calico District, San Bernardino County. pp. 337, 338, 339, 340, 343.

Geology of the Lava Bed District, San Bernardino County. pp. 349 and 350.

Geology in the region of Mineral Spring, Siskiyou County. pp. 451, 452; etc., etc.

J. J. CRAWFORD, State Mineralogist.

Twelfth Report (Second Biennial) of the State Mineralogist, for the two years ending September 15, 1894. Sacramento, 1894. 541 pp. Maps and illustrations.

This report contains an article on—

The auriferous conglomerate in California; by R. L. Dunn.

Preliminary report on the mineral deposits of Inyo, Mono, and Alpine Counties; by H. W. Fairbanks.

Ancient channel system of Calaveras County; by W. H. Storms.

Geology of northern Ventura, Santa Barbara, San Luis Obispo, Monterey, and San Benito Counties; by H. W. Fairbanks.

Bulletin No. 2. San Francisco, June, 1894. Methods of mine-timbering; by W. H. Storms. Sacramento, 1894. 58 pp., with illustrations. (A second edition was issued in 1896.)

Bulletin No. 3. San Francisco, August, 1894. The gas and petroleum yielding formations of the Central Valley of California; by W. L. Watts. Sacramento, 1894. 100 pp. Maps and illustrations.

Bulletin No. 4. San Francisco, September, 1894. Catalogue of California fossils, Parts II, III, IV, and V; by Dr. J. G. Cooper. Sacramento, 1894. 6 plates. (Part I was published in the Seventh Annual Report of the State Mineralogist for 1887.)

The following new species are described and figured:

CRETACEOUS AND EOCENE FOSSILS—*Teretra Wattsiana, Surcula crenatospira, S. monilifera, S. inconstans, Pleurotoma Perkinsiana, P. decipiens, Drillia ullreyana, Mangilia suturalis, Cordiera gracillima, Cancellaria Irelaniana, Ancilla* (*Oliverato*) *Californica, Bittium longissimum, Cerithium Fairbanksi, Potamides carbonicola, P. Davisiana, Fusus supraplanus, Mitra simplicissima, Stomatia intermedia, Calliostoma Kempiana, Tornatella normalis, Bulla assimilata, Tornatina erratica, Siphonaria capuloides, Astarto semidentata, Crassatella lomana, Cucul-*

læa Bowersiana, Corbula triangulata, Mytilus dichotomus, Crenella Santana, Megerlia dubitanda, Waldheimia imbricata.

TERTIARY-MIOCENE AND PLIOCENE—***Agasoma Barkerianum, Tropho-sycon*** (n.subgen.), ***Agasoma? (Trophosycon) Kernianum.***

FRESH-WATER FOSSILS—***Limnea Contracosta; Planorbis Pabloanus; Anodonta (Nuttalliana) lignitica; Amnicola Yatesiana; Pinna Alamedensis,*** Yates; ***P. Venturensis,*** Yates; ***Pecten discus,*** Conrad; ***Liropecten estrellanus,*** Conrad.

Bulletin No. 5. San Francisco, October, 1894. The cyanide process, its practical application and economical results; by Dr. A. Scheidel. Sacramento, 1894. 140 pp.

Catalogue of West North American and many foreign shells, with their geographical ranges. For labels, exchange, and check-lists, with a supplement. By J. G. Cooper. Printed for the State Mining Bureau, April, 1894. Sacramento, 1894.

Bulletin No. 6. California gold mill practices; by Ed. B. Preston. Sacramento, 1895. 85 pp.

Bulletin No. 7. Showing, by counties, the mineral productions of California for the year 1894; by Charles G. Yale. Sacramento, 1895. Tabular sheet.

Bulletin No. 8. Showing, by counties, the mineral productions of California for the year 1895; by Charles G. Yale. Sacramento, 1896. Tabular sheet.

Bulletin No. 9. Mine drainage, pumps, etc.; by Hans C. Behr. Sacramento, 1896. 200 pp. 206 illustrations.

CALIFORNIA SENATE AND ASSEMBLY DOCUMENTS.

California Senate and Assembly Journal, 15th Session.

Transactions California State Agricultural Society during the year 1863. Gives a list of gold mines. pp. 101–118.

Mining Review for 1863. Contains an article on placer gold mining; also a notice of silver mining, of quartz gold and silver mining, and of copper, coal, iron, petroleum and asphaltum, quicksilver mines, etc. pp. 176–193.

California Senate and Assembly Journal, 16th Session, 1866. Vol. 3, pp. 314–356.

Gives an account of California marble, p. 314.

Mining Review for 1865. Gives the extent of the mining field, variety of ore, mineral products, placer and surface diggings, quartz mining, silver mines, coal, quicksilver, petroleum, etc. pp. 315–334.

Annotated catalogue of the principal mineral species hitherto recognized in California and adjoining States and Territories; by W. P. Blake. March, 1866. pp. 335–356.

Notes on the geographical distribution and geology of the precious metals and valuable minerals of the Pacific Slope. pp. 359–364. [Prof. W. P. Blake was appointed the Geologist of the State Board of Agriculture in 1866, and made a report on the minerals of California under the above title. The report was also published in pamphlet form, with the same title. Reviewed Amer. Jour. Sci., Vol. 42, 1866, pp. 114–118.]

The same volume also contains a Report of Assembly Committee on Mines and Mining Interests, concerning the State Geological Survey; also, the Report of the State Geologist for 1863–64.

California Senate and Assembly Journal, 17th Session. No. 3.

Gold, silver, platinum, and rare metals. Sacramento. 1867.

CALIFORNIA STATE UNIVERSITY.

Report on Mount Diablo coals; by S. B. Christy. In reports to the President of the University, from the Colleges of Agriculture and the Mechanic Arts, pp. 70–74. Sacramento, 1877.

Report on the genesis of cinnabar deposits; by S. B. Christy. Berkeley, 1878.

Report of Professor J. D. Whitney to the honorable the Board of Regents of the University of California. In Biennial Report of the Regents of the University of California for the years 1877–79, pp. 82–85. Sacramento, 1879.

List of recorded earthquakes in California, Lower California, Oregon, and Washington Territory. Compiled from published works and from private information, by Edward S. Holden. Printed by direction of the Regents of the University of California. Sacramento, 1887. 78 pp.

Bulletin of the building-stones of California; by A. Wendell Jackson. California University, Berkeley, 1888. Supplement to Secretary's report.

This paper gives notes and microscopic examinations of Santa Susanna sandstones, Henly sandstones, Campo Seco tufa, Colton marbles, etc.

List of printed maps of California; by J. C. Rowell. Univ. of Cal., Library Bull. No. 9. Berkeley, 1887.

The geology of Carmelo Bay, by Andrew C. Lawson; with chemical analysis and coöperation in the field, by Juan de la C. Posada. Univ. of Cal., Bull. Dept. of Geology, Vol. 1, pp. 1–59, pls. 1–4. Berkeley, 1893.

This report contains a general statement of the geology of the district survey, with special chapters on the granites and eruptive rocks.

The soda-rhyolite north of Berkeley; by Charles Palache. Univ. of Cal., Bull. Dept. of Geology, Vol. 1, No. 2, pp. 61–72, pl. 5. Berkeley, 1893.

The eruptive rocks of Point Bonita; by F. Leslie Ransome. Univ. of Cal., Bull. Dept. of Geology, Vol. 1, No. 3, pp. 71–114, pls. 6–7. Berkeley, 1893.

The Post Pliocene diastrophism of the coast of Southern California; by Andrew C. Lawson. Univ. of Cal., Bull. Dept. of Geology, Vol. 1, No. 4, pp. 115–160, pls. 8–9. Berkeley, 1893.

The lherzolite-serpentine and associated rocks of the Potrero, San Francisco. On a rock from the vicinity of Berkeley, containing a new soda Amphibole; by Charles Palache. Univ. of Cal., Bull. Dept. of Geology, Vol. 1, Nos. 5–6, pp. 161–192, pls. 10–11. Berkeley, 1894.

The geology of Angel Island, by F. Leslie Ransome; with a note on the Radiolarian chert from Angel Island and from Buri-buri Ridge, San Mateo County, California. Univ. of Cal., Bull. Dept. of Geology, Vol. 1, No. 7, pp. 193–240, pls. 12–14. Berkeley, 1894.

The Radiolaria (suborder *Sphæroidea*) described in this report are of the genera *Cenosphæra*, *Carposphæra*, *Cenellipsis*, *Ellipsidium*, *Lithapium*; suborder *Discoidea*, genera *Tripocyclia*, *Hagiastrum*; suborder *Cyrtoidea*, genera *Dictyomitra*, *Lithocampe*, and *Sethocapsa*.

The geomorphogeny on the coast of Northern California; by Andrew C. Lawson. Univ. of Cal., Bull. Dept. of Geology, Vol. 1, No. 8, pp. 241–272. Berkeley, 1894.

On analcite diabase from San Luis Obispo County, California; by Harold W. Fairbanks. Univ. of Cal., Bull. of Geology, Vol. 1, No. 9, pp. 273–300, pls. 15–16. Berkeley, 1895.

On Lawsonite, a new rock-forming mineral from the Tiburon Peninsula, Marin County, California; by F. Leslie Ransome. Univ. of Cal., Bull. Dept. of Geology, Vol. 1, No. 10, pp. 301–312, pl. 17. Berkeley, 1895.

Critical periods in the history of the earth; by Joseph Le Conte. Univ. of Cal., Bull. Dept. of Geology, Vol. 1, No. 11, pp. 313–336. Berkeley, 1895.

A list of type specimens in the Geological Museum of the University of California, which have served as originals for figures and descriptions in the palæontology of the State Geological Survey of California under J. D. Whitney. Compiled for the use of workers in California geology, by John C. Merriam. Univ. of Cal., Bull. Dept. of Geology. Berkeley, 1895. 3 pp.

In a few cases the supposed type differed slightly, but unessentially, from the figure. Names of such species are followed in the list by an interrogation point.

CRETACEOUS.

Callianassa Stimpsoni, Gabb; Vol. I, pl. 9, fig. 1*a*, 1*b*.

Amm. (Haploceras) Breweri, Gabb; Vol. I, pl. 10, fig. 7.
Amm. Cooperi, Gabb; Vol. I, pl. 14, fig. 23, 23*a*.
Amm. Haydeni, Gabb; Vol. I, pl. 10, fig. 8.
Amm. jugalis, Gabb; Vol. I, pl. 10, fig. 5.
Amm. Peruvianus, Von Buch; Vol. I, pl. 10, fig. 9.
Amm. (Hoplites) Rémondi, Gabb; Vol. I, pl. 12, fig. 14.
Amm. (Phylloceras) ramosus, Gabb; Vol. I, pl. 11, fig. 12, pl. 12, fig. 12*b*.
Amm. suciaensis, Meek; Vol. I, pl. 21, fig. 11.
Amm. Tehamaensis, Gabb; Vol. I, pl. 10, fig. 4.
Baculites Chicoensis, Trask; Vol. I, pl. 14, fig. 29.
Beleminites impressus, Gabb; Vol. I, pl. 9, fig. 2.
Crioceras latus, Gabb; Vol. I, pl. 15, fig. 25.
Helicancyclus æquicostatus, Gabb; Vol. I, pl. 13, fig. 20.
Helicoceras declive, Gabb; Vol. I, pl. 28, fig. 200, 200*a*.
Helioceras Breweri, Gabb (?); Vol. I, pl. 14, fig. 22.

Actæonina Californica, Gabb; Vol. I, pl. 19, fig. 68 (fragments).
Actæonina pupoides, Gabb; Vol. I, pl. 19, fig. 67.
Chemintzia planulata, Gabb; Vol. I, pl. 19, fig. 70.
Cylindrites brevis, Gabb; Vol. I, pl. 29, fig. 223.
Eripachya Hoffmanni, Gabb; Vol. I, pl. 18, fig. 41.
Fusis Averilli, Gabb; Vol. I, pl. 18, fig. 34.
Fusus Kingi, Gabb; Vol. I, pl. 28, fig. 204.
Globiochonca Rémondi, Gabb; Vol. I, pl. 19, fig. 69.
Lunatia Conradiana, Gabb; Vol. I, pl. 29, fig. 219.
Lysis duplicostata, Gabb; Vol. I, pl. 21, fig. 98.
Pugnellus manubriatus, Gabb (?); Vol. I, pl. 29, fig. 229, 229*a*.
Ringinella pinguis, Gabb; Vol. I, pl. 29, fig. 221*a*.
Tessarolax distorta, Gabb (?); Vol. I, pl. 20, fig. 82, 82*b*.
Turritella Chicoensis, Gabb; Vol. I, pl. 21, fig. 91.
Turritella seriatim-granulata, Gabb; Vol. I, pl. 20, fig. 88.
Turritella Veatchi, Gabb (?); Vol. I, pl. 20, fig. 90.

Anatina lata, Gabb; Vol. I, pl. 22, fig. 126.
Anomia lineata, Gabb; Vol. I, pl. 26, fig. 193.
Arca decurtata, Gabb; Vol. I, pl. 31, fig. 265, 265*a*.
Arca gravida, Gabb; Vol. I, pl. 30, fig. 264.
Astarte tuscana, Gabb; Vol. I, pl. 30, fig. 257.
Aucella Piochi, Gabb; Vol. I, pl. 25, fig. 173, 174.
Corbula cultriformis, Gabb; Vol. I, pl. 22, fig. 122.
Cyprinella (*Diodus*) *tenuis*, Gabb; Vol. I, pl. 23, fig. 151*a*.
Dosinia inflata, Gabb; Vol. I, pl. 23, fig. 149.
Homomya (*Panopea*) *concentrica*, Gabb; Vol. I, pl. 22, fig. 119.
Lithophagus oviformis, Gabb; Vol. I, pl. 25, fig. 168.
Martesia clausa, Gabb; Vol. I, pl. 22, fig. 115.
Meekia navis, Gabb; Vol. I, pl. 25, fig. 180.
Meekia radiata, Gabb; Vol. I, pl. 25, fig. 179*a*.
Meretrix longa, Gabb; Vol. I, pl. 23, fig. 147.
Meretrix ovalis, Gabb; Vol. I, pl. 30, fig. 251.
Modiola cylindrica, Gabb; Vol. I, pl. 25, fig. 167.
Mytilus pauperculus, Gabb; Vol. I, pl. 25, fig. 165.
Ostrea Breweri, Gabb; Vol. I, pl. 26, fig. 191.
Pholadomya Breweri, Gabb; Vol. I, pl. 22, fig. 123.
Pholadomya nasuta, Gabb; Vol. I, pl. 30, fig. 124.
Pinna Breweri, Gabb; Vol. I, pl. 25, fig. 175.
Tellina decurta, Gabb; Vol. I, pl. 23, fig. 137.
Tellina monilifera, Gabb (?); Vol. I, pl. 22, fig. 134, 134*a*.
Tellina ooides, Gabb; Vol. I, pl. 22, fig. 135, 135*a*.
Terebratella obesa, Gabb (?); Vol. I, pl. 26, fig. 194.
Trigonia Gibboniana, Gabb; Vol. I, pl. 25, fig. 178.
Trigonia Tryoniana, Gabb; Vol. I, pl. 25, fig. 176.
Venus (*Chione*) *varians*, Gabb; Vol. I, pl. 23, fig. 140.

Flabellum Rémondianum, Gabb; Vol. I, pl. 26, fig. 199.

Astrocænia (*?*) *petrosa*, Gabb (?); Vol. I, pl. 31, fig. 274, 274*a*.

EOCENE (TEJON).

Fusus martinez, Gabb; Vol. I, pl. 18, fig. 32.
Margaritella crenulata, Gabb; Vol. I, pl. 20, fig. 74.
Neptunea supraplicata, Gabb; Vol. I, pl. 18, fig. 40.

Neptunea gracilis, Gabb; Vol. I, pl. 18, fig. 42.
Trachytriton (Tritonium) Diegoensis, Gabb; Vol. I, pl. 18, fig. 44.
Crypta (spirocrypta) pileum, Gabb (?); Vol. I, pl. 29, fig. 233, 243*b*.

Arca Horni, Gabb; Vol. I, pl. 30, fig. 263.
Avicula pellucida, Gabb; Vol. I, pl. 25, fig. 172.
Barbatia Morsei, Gabb (?); Vol. I, pl. 32, fig. 286.
Dosinia gyrata, Gabb; Vol. I, pl. 23, fig. 148.
Lucina cumulata, Gabb; Vol. I, pl. 24, fig. 254.
Mysia polita, Gabb; Vol. I, pl. 30, fig. 256.
Mytilus ascia, Gabb; Vol. I, pl. 30, fig. 259.
Neæra dolabræformis, Gabb (?); Vol. I, pl. 22, fig. 125.
Pectunculus (Axnixa) cor, Gabb; Vol. I, pl. 31, fig. 268, 268*a*.
Stalagmium (Crenella) concentricum, Gabb; Vol. I, pl. 24, fig. 169.
Unio penultimus, Gabb (?); Vol. I, pl. 24, fig. 164.

MIOCENE.

Cancer Breweri, Gabb; Vol. II, pl. 1, fig. 1.

Scutella Gibbsi, Gabb; Vol. II, pl. 13, fig. 66.

Echinarachinus Brewerianus, Gabb; Vol. II, pl. 12, fig. 64.

Ancillaria Fishi, Gabb (?); Vol. II, pl. 2, fig. 15.
Indet; Vol. II, pl. 3, fig. 29.
Indet; Vol. II, pl. 3, fig. 30.
Triptera clavata, Gabb; Vol. II, pl. 1, fig. 2.
Trochita inornata, Gabb (?); Vol. II, pl. 14, fig. 8.

Conchocele disjuncta, Gabb; Vol. II, pl. 7, fig. 48.
Modiola multiradiata, Gabb (?); Vol. II, pl. 8, fig. 52.
Ostrea Attwoodi. Gabb (?); Vol. II, pl. 11, fig. 58*b*.
Ostrea Tayloriana, Gabb; Vol. II, pl. 12, fig. 60.
Tapes truncata, Gabb; Vol. II, pl. 7, fig. 44.
Venus (Chione) pertenuis, Gabb; Vol. II, pl. 5, fig. 37.
Venus (Chione) Whitneyi, Gabb; Vol. II, pl. 5, fig. 40.

PLIOCENE.

Arca sulcicosta, Gabb; Vol. II, pl. 9, fig. 53.
Callista (Standella) Voyi, Gabb; Vol. II, pl. 5, fig. 41.
Gari (Psammocola) alata, Gabb; Vol. II, pl. 5, fig. 36.
Lucina (Here) Richthofeni, Gabb; Vol. II, pl. 8, fig. 49.
Zirphæa dentata, Gabb; Vol. II, pl. 3, fig. 31, 31*a*.

QUATERNARY.

Cancellaria (Euclia) tritonidea, Gabb; Vol. II, pl. 2, fig. 18.
Clathurella Conradiana, Gabb (?); Vol. II, pl. 1, fig. 12.
Muricidea paucivaricata, Gabb; Vol. II, pl. 14, fig. 1.
Surcula (Pleurotoma) Carpenteriana, Gabb; Vol. II, pl. 1, fig 8.
Surcula (Pleurotoma) Tryoniana, Gabb; Vol. II, pl. 1, fig. 9.

Mercenaria perlaminosa, Gabb; Vol. II, pl. 5, fig. 38.
Pecten Cerroensis, Gabb; Vol. II, pl. 9, fig. 55.

On Malignite, a family of basic, plutonic, orthoclase rocks, etc.; by Andrew C. Lawson. Univ. of Cal., Bull. Dept. of Geology, Vol. 1, No. 12, pp. 371–428. Berkeley, 1896.

Sigmogomphius Le Contéi, a new castoroid rodent from the Pliocene, near Berkeley, Cal.; by John C. Merriam. Univ. of Cal., Bull. Dept. of Geology, Vol. 1, No. 13, pp. 363–370. Berkeley, 1896.

The Great Valley of California: a criticism of the theory of isostasy; by F. Leslie Ransome. Univ. of Cal., Bull. Dept. of Geology, Vol. 1, No. 14, pp. 371–428. Berkeley, 1896.

The geology of Point Sal; by H. W. Fairbanks. Univ. of Cal., Bull. Dept. of Geology, Vol. 2, No. 1, pp. 1–92, pls. 1–2. Berkeley, 1896.

On some Pliocene Ostracoda from near Berkeley; by Frederick Chapman. Univ. of Cal., Bull. Dept. of Geology, Vol. 2, No. 2, pp. 93–100, plate 3.

PART II.

Publications of the United States Government.

SENATE AND HOUSE DOCUMENTS.

Report of the Exploring Expedition to the Rocky Mountains in 1842, and in Oregon and North California in the years 1843–44; by Bvt. Capt. J. C. Fremont, U. S. Army. Washington, 1845. 693 pp., 24 plates, and 3 maps. 28th Cong., 2d sess., Senate Doc. 174.

The first part of this report was a reprint of the expedition of 1842. (Senate Doc. 243, 27th Cong., 3d sess., 1842.)

The report contains a few geological notes of California, and a description of the fossils, by James Hall. The specimens described are all from Muddy Creek, Wyoming.

Geographical memoir upon Upper California in illustration of his map of Oregon and California; by John Charles Frémont. Addressed to the Senate of the United States. Washington, 1848. 67 pp. map. (30th Cong., 1st sess., Senate Misc. Doc. 148.)

Map of Oregon and Upper California, from the surveys of John C. Frémont and other authorities. Drawn by C. Preuss under the order of the Senate of the United States. Washington, 1848. Scale, 1:3,000,000.

Notes of a military reconnoissance from Fort Leavenworth, in Missouri, to San Diego, in California; including parts of the Arkansas, Del Norte, and Gila Rivers; by Maj. W. H. Emory, U. S. Army. Washington, 1848. 416 pp. 41 plates and map. (30th Cong., 1st sess., Ex. Doc. 41.)

Report of Lieut.-Col. P. St. George Cooke of his march from Santa Fé, New Mexico, to San Diego, Upper California. Washington, 1848. 13 pp. and map. (30th Cong., 1st sess., Ex. Doc. 41, pp. 551–563.)

Journal of Capt. A. R. Johnson, U. S. Army. (Expedition from Santa Fé to San Diego.) Washington, 1848. 48 pp. (30th Cong., 1st sess., Ex. Doc. 41, pp. 567–614.)

Journal of the march of the Mormon Battalion of Infantry Volunteers, under the command of Lieut.-Col. P. St. George Coöke, from Santa Fé, New Mexico, to San Diego, California. Washington, 1849. 85 pp. (30th Cong., spec. sess., Senate Doc. 2.)

United States Exploring Expedition, under the command of Charles Wilkes, U. S. Navy. Vol. X, Geology, by James D. Dana. Philadelphia, 1849. pp. xii, 9, and 756. 5 maps and folio atlas of 21 plates.

Only two hundred copies of this report were published. (Letter of J. D. Dana, September 2, 1890.)

The author gives an account of the geology of Shasta Mountains, also that of San Francisco Bay, with a description of the fossils of Astoria, Oregon.

A synopsis of this report was published in Wilkes's Western America, including California and Oregon, with maps of those regions and of "The Sacramento Valley," from actual surveys. Philadelphia, 1849.

REPORTS OF THE SECRETARY OF WAR.

Information in relation to the geology of California:

Report of P. T. Tyson upon the geology of California. 31st Cong., 1st sess., Senate Ex. Doc. 47. Washington, 1850. 74 pp. 9 sections and 1 map.

This report contains articles on the geology of part of the Sierra Nevada; geology of the Coast Range; geological structure of Sacramento Valley; review of the geological changes in California; gold regions of the Sierra Nevada; the quicksilver mines; other mineral resources, and their industrial applications.

Report by General Smith, dated October 7, 1849. pp. 75–108.

Report of Lieutenant Talbot to General Smith, dated October 5, 1849. pp. 108–116.

Report of Professor Frazer on minerals forwarded by General Smith; dated March 21, 1850. pp. 116–117.

Report of General Riley, dated January 1, 1850. pp. 118–119.

Report of Lieutenant Ord to General Riley, dated October 31, 1849. pp. 119–127.

Part 2. Report of the Secretary of War in further compliance with the resolution of the Senate, calling for copies of Report on the Geology and Topography of California. Washington, 1850. 37 pp., and 3 maps. (31st Cong., 1st sess., Senate Ex. Doc. 47.)

This report contains: A topographical memoir accompanying maps of the Sacramento Valley, etc.; by Lieut. G. H. Derby. pp. 2–16.

Reconnoissance made by Capt. W. H. Warner of a route through the Sierra Nevada by the upper Sacramento. pp. 16–34.

Exploration of Monte Diablo, and the valley lying between this mountain and the southern shore of Suisun Bay; by Lieut. R. S. Williamson. pp. 34–37.

Geology and industrial resources of California; by Philip T. Tyson. Baltimore, 1851. xxxiv, 127, and 37 pp. 9 sections and three maps.

A republication of the above report, with an introduction and an index.

The Report of Secretary of War. 1850. (31st Cong., 2d sess., Senate Ex. Doc. 1.)

The report of Major D. H. Vinton contains an account of borings near Benicia. pp. 278–279.

T. Butler King's report on California. 1850. (31st Cong., 1st sess., Ho. of Rep. Ex. Doc. 59.)

This document was published in Washington in another form by Gideon & Co., 1850. 72 pp. 8vo.

The author gives an account of the geology of the Gold Regions.

Letter from Col. Richard B. Mason. (31st Cong., 1st sess., Ho. of Rep. Doc. 17, 1850, pp. 528–536.)

This letter is the first official report on the discovery of gold in California. Colonel Mason states that on the 12th of June, 1848, in company with Lieut. W. T. Sherman, he started on a tour through the northern part of California to visit the newly discovered gold placer region in the valley of the Sacramento. He gives a description of the country along the American River and an historical account of the mining regions. He also gives a description of the quicksilver mines near San José.

Tour of the gold regions; by Bvt. Brig.-Gen. Bennett Riley. (31st. Cong., 1st sess., Ho. of Rep. Doc. 17, 1850, pp. 785–792.)

United States and Mexican Boundary Survey, under the orders of Lieut.-Col. W. H. Emory. Geology and Palæontology of the Boundary, by James Hall; pp. 103–140, Part 2. Description of Cretaceous and Tertiary Fossils, by T. A. Conrad; pp. 141–165. (34th Cong., 1st sess., Senate Ex. Doc. 108. Washington, 1857.)

Chapter V contains description of the geology of Southern California, with a section of lignite bluff near San Diego.

Notes on route from near the Tejon Pass, through western New Mexico and the Colorado to Santa Fé in the fall of 1853; by Capt. F. C. Aubrey. 12 pp. [Published by Congress in 1854 and in the California journals.]

This was the route through the gold country on the head (southern) waters of the San Juan and the upper branches of the Rio Salodo, or Salinas, of the Gila River.

Report upon Pacific wagon roads. Washington, 1858. (35th Cong., 2d sess., Ho. of Rep. Ex. Doc. 108, Senate Doc. 36.)

Report of Survey on the Union and Central Pacific Railways; by W. T. Twining. Washington, 1875. (44th Cong., 2d sess., Ho. of Rep. Doc. 38.)

Mining débris in California. Preliminary report; by Col. Geo. H. Mendell. Submitted January 31, 1881.

Mining débris in California rivers. Letter of the Secretary of War. A final report upon the system to prevent further injury to the navigable waters of California from mining débris. 1882. 110 pp. 2 maps. (47th Cong., 1st sess., Ho. of Rep. Ex. Doc. 98.)

Mining débris in California. Letter of the Secretary of War. Report of Board of Government Engineers respecting the adjustment of the conflict between the mining and farming sections, and the rehabilitation of the mining industry in California. 1891. 124 pp. 2 maps. (Ex. Doc. 267, H. R., 51st Cong., 2d sess.)

e future of silver, by Suess Edward; translated by Robert Stein, U. S. Geol. Survey. Washington, 1893. 101 pp. (53d Cong., 1st sess., Senate Misc. Doc. 95.)

The author gives a sketch of the California gold fields.

U. S. NAVY DEPARTMENT.

ter from the Secretary of the Navy, inclosing report of experiments on the coal of the Pacific Coast, in compliance with a resolution of the House of March 22, 1872. (42d Cong., 2d sess., Ho. of Rep. Ex. Doc. 206.)

This report of Chief Engineer B. F. Isherwood, U. S. Navy, contains a report on the brown coal from Mount Diablo coal mines of California.

PORTS OF EXPLORATIONS AND SURVEYS

For a Railroad from the Mississippi River to the Pacific Ocean.

IFIC RAILROAD REPORTS, Vol. III. Résumé of a geological reconnoissance, extending from Napoleon, at the junction of the Arkansas with the Mississippi, to the Pueblo de los Angeles, in California; by Jules Marcou. pp. 165–175.

This résumé was reprinted from the preliminary report of Lieutenant Whipple. Chap. VI, p. 40, House Doc. 129. Washington, 1855.

The report has a geological map of the route explored near the parallel of 35° north latitude, from the Mississippi River to the Pacific Ocean.

— Vol. V. Routes in California to connect with the routes near the 35th parallel and 32d parallel explored by Lieut. R. S. Williamson in 1853. Geological report by William P. Blake. Washington, 1856. (33d Cong., 2d sess., Senate Ex. Doc. 78.)

This report contains general observations upon the geology of the route:

Chapter I. San Francisco to the San Joaquin River.
II. Grayson's Ferry, on the San Joaquin, to Fort Miller.
III. Fort Miller and the vicinity; Fort Miller to Ocoya Creek.

IV. Ocoya Creek to the Tejon.
V. Tejon to San Amedio; Cañada de las Uvas.
VI. Tejon to the Great Basin and Pass of San Francisquito; Pass of San Francisquito to the Mojave River.
VII. Mojave River, by Williamson's Pass, to San Fernando and Los Angeles; Los Angeles to San Bernardino; Cajon Pass.
VIII. San Bernardino to the Colorado Desert; Colorado Desert to Carrizo Creek and Warner's Valley.
IX. Warner's to the Colorado Desert; Colorado Desert to the mouth of the Gila; Camp Yuma and the vicinity.
X. Fort Yuma to Carrizo Creek; Carrizo Creek to San Diego.
XI. Observations on the orography and general features of relief of the middle and southern portions of California.
XII. Geology of the vicinity of San Francisco.
XIII. Tertiary formations of Ocoya Creek, Monterey, and other localities.
XIV. Observations on the Tulare Valley.
XV. Geology of the Tejon Pass and Cañada de las Uvas; section of the Sierra Nevada.
XVI. Observations on the southern part of the Great Basin.
XVII. The Colorado Desert.
XVIII. Notes on the Gold Region.
XIX. Building materials; coal; lignite; bitumen.
XX. Metals, ores, and minerals.

Appendix, Article I. Notice of the fossil fish; by Louis Agassiz. pp. 313–316. plate 1.

The following species from Ocoya Creek are described and figured: *Echinorhinus Blakei*, n.sp.; *Scymnus occidentalis*, n.sp; *Galeocerdo productus*, n.sp.; *Prionodon antiquus*, n.sp.; *Hemipristic heteropleurus*, n.sp.; *Carcharodon rectus*, n.sp.; *Oxyrhina plana*, n.sp.; *O. tumula*, n.sp.; *Lamna clavata*, n.sp.; *L. ornata*, n.sp.; *Zygobates* sp.?

Appendix, Article II. Descriptions of the fossil shells; by T. A. Conrad. pp. 317–329. plates 2–9.

From Cañada de las Uvas: *Cardium linteum*, n.sp.; *Dosinia alta*, n.sp.; *Meretrix Uvasana*, n.sp.; *M. Californiana*, n.sp.; *Crassatella Uvasana*, n.sp.; *C. alta*, Conrad; *Mytilus humerus*, n.sp.; *Cardita planicosta; Natica œtites*, Conrad; *N. gibbosa*, Lea; *N. alveata; Turritella Uvasana*, n.sp.; *Volutatithes Californiana*, n.sp.; *Busycon? Blakei*, n.sp.; *Clavatula Californica*, n.sp.

From Ocoya Creek: *Meretrix decisa*, n.sp.; *Natica Ocoyana*, n.sp.; *N. geniculata*, n.sp.; *Bulla jugularis*, n.sp.; *Pleurotoma transmontana*, n.sp.; *P. Ocoyana*, n.sp.; *Syctopus Ocoyana*, n.sp.; *Turritella Ocoyana*, n.sp.; *Colus arctatus*, n.sp.; *Tellina Ocoyana*, n.sp.; *Pecten Nevadanus*, n.sp.; *P. catilliformis*, n.sp.; *Cardium* sp.?; *Arca* sp.?; *Solen* sp.?; *Dosinia* sp.?; *Venus* sp.?; *Cytherea decisa*, Conrad.

From San Diego: *Cardium modestum*, n.sp.; *Nucula decisa*, n.sp.; *Corbula Diegoana*, n.sp.; *Tellina Diegoana*, n.sp.; *Mactra Diegoana*, n.sp.; *Narica Diegoana*, n.sp.; *Trochita Diegoana*, n.sp.; *Crucibulum spinosum*, n.sp.

From Monterey County: *Meretrix uniomeris*, n.sp.; *Tellina congesta*, n.sp.; *Modiola contracta*, n.sp.

From Tulare Valley: ***Meretrix Tularena***, n.sp.; ***Arca microdonta***, n.sp.; ***Stramonita petrosa***, n.sp.

From San Pedro: ***Tellina Pedroana***, n.sp.; ***Tapes diversum***, n.sp.; ***Saxicava abrupta***, n.sp.; ***Petricola Pedroana***, n.sp.; ***Schizothœrus Nuttalli***, n.sp.; ***Mytilus Pedroana***, n.sp.; ***Penitella spelæa***, n.sp. (Recent); ***Fissurella crenulata***, Sow.; ***Buccinum interstriatum?***

From Carmello: ***Lutraria Traskei***, n.sp.

From Colorado Desert: ***Pecten deserti***, n.sp.; ***Anomia subcostata***, n sp.; ***Ostrea vespertina***, n.sp.; ***O. Heermanni***, n.sp.; ***Anodonta Californiensis***, Lea.

From San Fernando: ***Ostrea*** sp.? ***Pecten*** sp.?

From Benicia: ***Turritella biseriata***, n.sp.; ***Trochus*** sp.?

Appendix, Article IV. Letter from Prof. J. W. Bailey, describing the structure of the fossil plant from Posuncula River. p. 337. (This plant was from a bowlder in the bed of Kern River, west slope of the Sierra Nevada.)

PACIFIC RAILROAD REPORTS, Vol. VI. Geological report of routes in California and Oregon explored by Lieuts. R. S. Williamson and H. L. Abbott; by John S. Newberry. (33d Cong., 2d sess., Senate Ex. Doc. 78. 1857.)

This report contains the following:

Chapter I. Geology of the vicinity of San Francisco.
II. Geology of the Sacramento Valley.
III. Geology of the Western range, Sierra Nevada.
IV. Geology of Pit River and Klamath Basin.

—— Vol. VI, No. 2. Description of the Tertiary fossils collected on the survey; by T. A. Conrad.

The following species are described and figured in this report:

Schizopyga Californiana, n.sp., Santa Clara, Cal.
Cryptomya ovalis, n.sp., Monterey County.
Thracia mactropsis, n.sp., Monterey County.
Mya Montereyana, n.sp., Monterey County.
M.? subsinuata, n.sp., Monterey County.
Arcopagia medialis, n.sp., Monterey County.
Tapes linteatum, n.sp., California.
Arca canalis, n.sp., Santa Barbara.
A. trilineata, n.sp., Santa Barbara.
A. congesta, California.
Axinœa Barbarensis, n.sp., Santa Barbara.
Mulinia densata, n.sp., Santa Barbara.
Dosinia longula, n.sp., Monterey.
D. alta, n.sp., Monterey.
Pecten Pabloensis, n.sp., San Pablo Bay.
Pallium estrellanum, n.sp., Estrella Valley.
Janira bella, n.sp., Santa Barbara.
Ostrea titan, n.sp., San Luis Obispo.
Malea ringens; Dolium ringens (Cassis), Swainson.
Turritella altilira, n.sp., Gatun, Isthmus of Darien.
T. Gatunensis, n.sp, Gatun.

Triton, sp.?; *Cytherea* (*Meretrix*) *Dariena; Tamiosoma gregaria*, n.sp., Monterey County.

Pandora bilirata, n.sp., Santa Barbara.

Cardita occidentalis, n.sp., Santa Barbara.

Diadora crucibuliformis, n.sp., Santa Barbara.

The author discusses the age of the formation afterward called by the California geologists the Chico group. Newberry admits the Tertiary character of a part of the fossils, but is inclined to refer the formation to the Cretaceous, because of the presence in it of *Ammonites*, etc.

PACIFIC RAILROAD REPORTS, Vol. VII. Routes in California to connect with the routes near the 35th and 32d parallel and routes near the 32d parallel, between the Rio Grande and Pimas villages, explored by John G. Parke in 1854–55. Geological report by Thomas Antisell. (33d Cong., 2d sess., Senate Ex. Doc. 78. 1857.)

This report contains chapters on the physical geography of the Pacific Coast; geology of the Coast Ranges; Santa Clara Valley and Pajaro River Valley; Salinas River Valley; Santa Margarita Valley; Point Pinos Mountains and Sierra San José; Santa Maria River and Cuyama Valley; Santa Lucia Mountains; Valley of San Luis Obispo, Santa Barbara Mountains; geology of the Sierra Susanna and Monica; Plains of San Fernando; Los Angeles and San Bernardino; with the geology of the Cordilleras, etc.; Estrella River; Panza and Carrizo; Mojave River Valley; bituminous effusions; Quaternary period in California; geology of the district from San Diego to Fort Yuma, and from Fort Yuma to the Pimas villages; etc., etc.

—— Report on the Palæontology of the survey; by T. A. Conrad. Chapter XXIX, pp. 189–196, with 10 plates.

The author remarks that the Miocene of Santa Barbara contains a group of shells more analogous to the fossils of the Atlantic slope than to the existing shells of California; but it is evident that there must be subdivisions in the Tertiary deposits of California, which range between the Eocene and Pliocene periods, for the group of the Estrella Valley and Santa Ynez (Barbara) Mountains does not appear to contain one species, even, analogous to any in the Santa Barbara beds, and, on the contrary, some of them remind us of the existing Pacific fauna.

The author describes and figures the following new species:

From Santa Margarita, Salinas Valley: *Hinnetes crassa.*

From San Rafael Hills and Santa Barbara County: *Pecten Meeki; P. altiplicatus; Arcopagia unda.*

From Carrizo Creek, Colorado Desert, and Estrella River Valley: *Pecten deserti*, Conrad; *Pallium Estrellanum; Spondylus Estrellanus; Arcopagia unda; Cyclas Estrellana; Ostrea panzana; Glycimeris Estrellanus; Balanus Estrellanus; Astrodapsis Antiselli.*

From Santa Ynez and Santa Ynez Mountains: *Pecten discus; Pachydesma Inezana; Pecten magnolia; Crassatella collina; Mytilus*

Inezensis; Turritella Inezana; T. variata; Natica Inezana; Tapes Inezensis.

From San Buenaventura: *Tapes montana.*

From Pajaro River: *Venus Pajaroana.*

From Sierra Monica: *Cyclas permacra; Ostrea subjecta.*

From San Luis Obispo Valley: *Arca Obispoana.*

From Gaviota Pass: *Ostrea panzano; Mactra? Gaviotensis; Trochita costellata.*

From Salinas River, Monterey County: *Dosinia alta; D. longula; D Montana; D. subobliqua.*

From Ranch Triumpho, Los Angeles: *Lutraria transmontana; Axinea Barbarensis.*

Report of Mr. T. A. Conrad on the fossil shells collected in California by Wm. P. Blake, Geologist of the Expedition under the command of Lieut. R. S. Williamson, etc. Washington, 1855. 34 pp. (House Doc. 129.)

The fossils described in this report were afterward republished, with figures, in the fifth volume of Explorations and Surveys for a Railroad Route from the Mississippi River to the Pacific Ocean.

REPORTS ON MINERAL RESOURCES OF THE STATES AND TERRITORIES WEST OF THE MISSISSIPPI.

Report of 1867; by J. Ross Browne and James W. Taylor, U. S. Mining Commissioners. Washington, 1867. 360 pp.

Historical sketch of gold and silver mining on the Pacific Slope; by J. Ross Browne and J. W. Taylor. pp. 13–36.

Geological formation, etc., of Pacific Slope; by William Ashburner. pp. 37–49. (Contains articles on the gold-mining interest of California; characteristics of the gold belt; northern mining district; mining in the Sierras.)

Condition of gold and silver mining on the Pacific Coast; by J. Ross Browne and James W. Taylor. pp. 49–85.

The copper resources of the Pacific Slope; geological formation in which copper is found; by J. Ross Browne and James W. Taylor. Section V, pp. 138–169.

Quicksilver mines in California; New Almaden mines, products and exports. Section VI, pp. 170–178. (This article contains a description of the New Almaden mines, with extracts of a report by Prof. B. Silliman, Jr., from the Am. Jour. Sci. for September, 1864.)

Borax, sulphur, tin, and coal. Section VII, pp. 178–193. (Contains articles on the discovery of borax in California, etc.; reports on tin, from the Geological Survey of California, Vol. 1, p. 180; with report on

the coal mines of the West Coast of North America, by W. M. Gabb.)

Annotated catalogue of the principal mineral species hitherto recognized in California and adjoining States and Territories; by William P. Blake. Section IX, pp. 200–215. (This article also contains notes on the geological distribution and geology of the precious metals and valuable minerals on the Pacific Slope of the United States, with a section across the Mariposas.)

History of California; by E. Randolph. pp. 268–305.

Acquisition of California; by John W. Dwinelle. pp. 306–320.

Report of 1868; by J. Ross Browne, U. S. Mining Commissioner. Washington, 1868. 674 pp.

General condition of the mining interest; by J. Ross Browne. pp. 12–298.

Lower California geographical and physical features; by W. M. Gabb. pp. 630–639.

So little is accurately known in regard to the geology of Lower California, that it seems desirable to include this notice and a list of the works on Lower California in this bibliography. The most important publications with regard to the geology of Lower California are:

1. Notes on the geology of Baja California, Mexico; by W. Lindgren. Proc. Cal. Acad. Sci., 2d series, Vol. 1, 1888, p. 173; Vol. 2, 1889, p. 1; Vol. 3, 1890, p. 26.
2. Some geological notes are also found in the reports of the Mexican boundary and Pacific Railway surveys.
3. Geological sketch of Lower California; by S. I. Emmons and G. P. Merrill. Bull. Geol. Soc. Am., Vol. 5, 1894, pp. 489–514, with map.
4. Explorations in the Cape Region of Baja California; by Gustav Eisen. Proc. Cal. Acad. Sci., Vol. 5, 1895, p. 733; map.

The Mother Lode of California. pp. 14–19.

Miscellaneous minerals of Pacific Coast. pp. 207–266.

Agricultural resources of California. pp. 266–281.

Treasure shipments; precious metals, etc. pp. 289–298.

Report of 1869; by R. W. Raymond, U. S. Mining Commissioner. Washington, 1870. 256 pp.

This includes notes on the Almaden mines and a chapter on the Mother Lode of California.

Report of 1870; by R. W. Raymond, U. S. Mining Commissioner. Washington, 1870. 805 pp.

California mines; by W. A. Skidmore. pp. 13–87.

Dead rivers of California; by J. S. Hittell. pp. 63–67.

Report of 1870; by R. W. Raymond, U. S. Mining Commissioner. Washington, 1872. 566 pp.

Chapter on California mines; by W. A. Skidmore. pp. 11–92.

Deep placer mining in California; by W. A. Skidmore. pp. 52–90.

List of stamp-mills in California. Chapter 16.

Report of 1871; by R. W. Raymond. Washington, 1873. 566 pp.

Chapter on California; by W. A. Skidmore. pp. 13–140.
Diamonds in El Dorado County; by W. A. Goodyear. p. 27.

Report of 1872; by R. W. Raymond. Washington, 1873. 550 pp.

Chapter on California; by W. A. Skidmore. pp. 7–107.
List of mining claims in California. pp. 102–107.
Treatment of gold-bearing ores in California; by G. F. Deetken. Chapter 11.
Pliocene rivers of California; by A. W. Bowman. Chapter 16.
Hydraulic mining in California; by Chas. Waldeyer. Chapter 17.
This report also contains a geological map of the United States, by C. H. Hitchcock and W. P. Blake; also, a map showing a portion of the mining region in Placer and El Dorado Counties, and maps of Slate Creek Basin, Sierra County.

Report of 1873; by R. W. Raymond. Washington, 1874. 585 pp.

Chapter on California; by W. A. Skidmore. pp. 13–154.
Quicksilver in California; by Chas. G. Yale. pp. 27–29.
Beach sands of Gold Bluff; by A. W. Chase. pp. 145–147.
Mining and metallurgy of quicksilver in California; by Louis Janin, Jr. Chapter 11.
The geological formation of iron deposits in California is given on p. 44, extract from James D. Hague and Clarence King's report of the Sierra Iron and Mining Company.

Report of 1874; by R. W. Raymond. Washington, 1875. 540 pp.

Chapter on California; by W. A. Skidmore. pp. 11–194.
Seam mining. p. 81.
Geology of the Sierra Nevada in its relations to vein mining, with map and tabular exhibit of results of mining; by Amos Bowman. Chapter 18.
History of relative values of gold and silver. Chapter 19.
An abstract of Dr. J. G. Cooper's paper on the discovery of lignites in Amador County and other counties in the foothills of the Sierra Nevada is given on p. 75.

Report of 1875; by R. W. Raymond. Washington, 1877. 519 pp.

Chapter on California; by W. A. Skidmore. pp. 3–131.
Quicksilver in California; by J. B. Randol. pp. 4–21.
Extinct rivers of the auriferous belt of California; by C. J. Brown. pp. 65–68.
Geology of Plumas County, with map; by J. A. Edman. pp. 109–128.
Petroleum in California; by F. A. Clarke. pp. 21–22.

Report of 1880. Statistics of production of the precious metals in the United States for 1880; by H. C. Burchard, Director of U. S. Mint. Washington, 1881. 443 pp.

Contains chapter on California mines, by W. A. Skidmore and Chas. G. Yale; Contributions to California geology, by Melville Attwood; Auriferous gravels, by Chas. G. Yale.

Report of 1881; by H. C. Burchard, Director of U. S. Mint. Washington, 1882. 765 pp.

Contains chapter on California mines, by A. M. Lawver; Milling of gold quartz, by Melville Attwood; Mining machinery in California, by Chas. G. Yale; Gold from sulphurets, by Melville Atwood; Auriferous gravels of California, by John Hays Hammond; Old river-beds of the Sierra Nevada of California, by Jas. J. McGillivray.

Report of 1882; by H. C. Burchard, Director of U. S. Mint. Washington, 1883. 873 pp.

Contains chapter on California mines, by J. R. Hardenburg; Placer gold in California, by Henry G. Hanks.

Report of 1883; by H. C. Burchard, Director of U. S. Mint. Washington, 1884. 858 pp.

Contains chapter on California mines, by J. R. Hardenburg; Condition of mining in California, by W. A. Skidmore; Drift mining in California, by R. L. Dunn.

Report of 1884; by H. C. Burchard, Director of U. S. Mint. Washington, 1885. 644 pp.

Contains a chapter on California mining, by A. M. Lawver; Gold and silver mining in California, past, present, and prospective, by W. A. Skidmore; Forms in which gold occurs in nature, by W. P. Blake.

Reports of 1885, 1886, 1887, 1888; by Jos. P. Kimball, Director of U. S. Mint.

In each of these reports the chapter on California mining is by Israel Lawton.

Reports of 1889, 1890, 1891, 1892; by E. O. Leech, Director of U. S. Mint.

In each of these reports the chapter on California mining is by Chas. G. Yale, except in 1892, when it was by W. H. Dimond.

Reports of 1893, 1894, 1895; by R. E. Preston, Director of U. S. Mint.

In each of these reports the chapter on California mining is by Chas. G. Yale.

UNITED STATES COAST SURVEY.

Report of 1855. Observations on the physical geography and geology of the coast of California from Bodega Bay to San Diego; by W. P. Blake. pp. 376–398. 4 plates.

Part 2. Geology of the principal bays and ports from Point Reyes to San Diego:

1. Punta de los Reyes. The end of the point composed of granite; form of the point; Tertiary strata; etc.
2. San Francisco. Golden Gate; character of the shores; rocks forming the points of the peninsula of San Francisco; sandstone strata uplifted; quarries; probable age; metamorphosed rock; erupted rocks and serpentine alluvial deposits; sand dunes; etc.
3. Monterey. Point Pinos; Cypress Point; San Carlos; Point Pinos of granite; Tertiary strata; fossils and infusoria; rocks of Cypress Point; granite and conglomerate; rock formation of San Carlos Bay; Point Lobos.
4. San Luis Obispo and Santa Barbara. Recent Tertiary strata; mountains, probably of sandstone; resemblance to volcanic rocks.
5. San Pedro and vicinity. Absence of mountain ridges; banks of Tertiary strata; sandstone with sun-cracks; disturbance of the strata; fossils; bitumen.
6. San Diego. Tertiary strata forming rounded hills; Tertiary strata of the slope; fossils; trappean rock.
7. Islands near the coast. Probably composed of sandstone and shale; flexures of the strata of Santa Catalina; etc.

Notice of earthquake waves, etc.; by A. D. Bache. *Idem*, p. 342; also, in Report of 1862, p. 238.

U. S. CENSUS REPORTS.

Report on the physical and agricultural features of the State of California, with a discussion of the present and future of cotton production in the State; also, remarks on cotton culture in New Mexico, Utah, Arizona, and Mexico; by E. W. Hilgard. 10th U. S. Census Report, Vol. VI, part 2, 1884.

A general description of the geology of the State is given on page 8. The outlines of the physical geography of the State, pp. 7, 83.

Report of mineral industries of the United States. 11th U. S. Census Report, 1890.

Contains special reports as follows: Gold and silver, by R. P. Rothwell; Quicksilver, by James B. Randol; Coal, by John H. Jones; Petroleum, by J. D. Weeks; Natural gas, by J. D. Weeks; Asphaltum, by E. W. Parker; Stone, by W. C. Day; Precious stones, by G. F. Kunz; Infusorial earth, by E. W. Parker; Chapter on California mines, by Chas. G. Yale.

U. S. GEOGRAPHICAL AND GEOLOGICAL SURVEYS WEST OF THE 100TH MERIDIAN.

Lieut. GEO. M. WHEELER, U. S. Corps of Engineers, in charge.

Vol. III, Part 1. Report on the geology of portions of Nevada, Utah, California, and Arizona, examined in the years 1871–72; by G. K. Gilbert. Washington, 1875.

Annual report of Lieut. George M. Wheeler, for the fiscal year ending June 30, 1876.

Annual report of Chief of Engineers. 1876. Appendix JJ.

Report on the geology of a portion of Southern California; by Jules Marcou. *Idem*, Appendix H_1, pp. 378–392.

This report contains articles on the Pliocene rocks of Los Angeles; the sierra of Santa Monica; Sierra Madre; Pacoña or Pacoima Cañon; geology of the vicinity of the San Fernando Mission; the San Fernando sierra; asphaltum and mineral oil near San Francisquito Ranch; Sierra Liebre and California desert; Tertiary rocks, Cañada de las Uvas, Fort Tejon, and of California; glacial rocks of Southern California and Pike's Peak; mountain chains and their ages; Coast Range; sierras of San Fernando and Santa Monica; hills of Los Angeles, etc.

Report on the geological and mineralogical character of Southern California and adjacent regions; by Oscar Loew. *Idem*, Appendix H_2, pp. 393–419.

Report on the geology of the mountain ranges from La Veta Pass to the head of the Pecos; by A. R. Conkling. *Idem*, Appendix H_4, pp. 419–422.

ort of 1877. Geological report on the portions of Western Nevada and Eastern California between the parallels 30° 30′ and 38° 30′; by A. R. Conkling. Report of Chief of Engineers, 1877, Appendix H, pp. 1285–1295.

The area examined is bounded on the north by a line drawn through Truckee, Cal., and Washoe City, Nev.; on the east by the Mount Davidson range and the Como Mountains; on the south by Job's Peak and Pyramid Peak; and on the west by the Western summit and the Truckee Rivers. Nearly all this region is covered by granites, with occasional outbursts of basaltic rocks. No fossils were found, except at Carson City, at the State Prison quarries.

S. GEOLOGICAL AND GEOGRAPHICAL SURVEYS OF THE TERRITORIES.

F. V. HAYDEN, U. S. Geologist, in charge.

elfth Annual Report of the U. S. Geological and Geographical Survey of the Territories. A report of progress of the exploration in Wyoming and Idaho for the year 1878. In two parts. Part I. Washington, 1883.

On page 132, Dr. White describes *Productus giganteus*, Martin, from McCloud River, Shasta County, California.

UNITED STATES GEOLOGICAL SURVEY.

J. W. POWELL, Director.

port for 1883–84; by Albert Williams.

Contains: Report on coal fields of United States, pp. 14–143; Iron on the Pacific Coast, by C. G. Yale, pp. 286–290; Quicksilver reduction at New Almaden, by S. B. Christy, pp. 503–534; The asphaltum deposits of California, by E. W. Hilgard, pp. 938–948; with reports on other minerals.

th Annual Report, 1884–85. Division of Mesozoic Invertebrates, by Charles A. White. pp. 72–74. 1885.

The author states his conclusions in regard to the Chico and Tejon groups, and the auriferous slate series of California. He gives the name of *Wallala* group to a Cretaceous formation in Mendocino County.

Sixth Annual Report, 1884–85. Administrative report, by George F. Becker. pp. 67–70.

The author discusses the age and time of uplift of the Coast Range formations and the equivalency of different *Aucella*-bearing beds.

Report for 1885; by David T. Day.

Contains: Reports on coal of California, pp. 15–16; Petroleum, pp. 148–152; Iron on the Pacific Coast, by C. G. Yale, pp. 196–199; Quicksilver, pp. 284–296; with reports on other minerals.

Seventh Annual Report, 1885–86. Report on California division of geology, by George F. Becker. pp. 93–97. 1888.

References to the diabase pebbles, etc., at Steamboat Springs, Nev.; the relations of the early and the late Cretaceous of the Coast Ranges; the identity of the older strata of the Coast Ranges with the fossiliferous rocks at the southern end of the gold belt in the Sierra Nevada, and the age and history of the Chico and Tejon series, etc.

Report for 1886; by David T. Day.

Contains: Quicksilver, pp. 160–168; with reports on other minerals.

Report for 1887; by David T. Day.

Contains: Quicksilver, pp. 118–125; with reports on other minerals.

Report for 1888; by David T. Day.

Contains: Iron ores of Rocky Mountain division, by F. F. Chisolm, pp. 35–39; Quicksilver, pp. 97–107; with reports on other minerals.

Eighth Annual Report, 1889. Quaternary history of Mono Valley, California; by Israel C. Russell. pp. 261–394. 24 plates and 5 maps.

—— Geology of Lassen Peak District; by J. S. Diller. pp. 395–432. 7 plates.

This report contains an account of the geologic formations in the Lassen Peak district; auriferous slates series; carboniferous limestone; serpentine; age of the auriferous slate district. Cretaceous—Chico beds, composition, distribution, age of the fossils, upper and lower limits. Miocene—Composition of the Miocene strata, distribution and relations, fossils found in the Miocene strata, hypsographic and climatic conditions during the Miocene. Pliocene—Upheaval of the Piedmont region, structure of the Sierras, etc.

—— Summary of the quicksilver deposits of the Pacific Slope; by George F. Becker. pp. 961–985. 3 plates.

For list of contents, see Monograph XIII.

Report for 1889–90; by David T. Day.

Contains: Quicksilver, pp. 94–109; Petroleum, by Joseph D. Weeks, pp. 287–365; Borax, by Charles G. Yale, pp. 494–506; with reports on other minerals.

Report for 1891; by David T. Day.

Contains: Quicksilver, pp. 117–125; with reports on other minerals.

Report for 1892; by David T. Day.

Contains: Quicksilver ore deposits, by George F. Becker, pp. 139–168; with reports on other minerals.

Report for 1893; by David T. Day.

Contains: Quicksilver, pp. 111–118; with reports on other minerals.

Report for 1894; by David T. Day.

The report forms Parts III and IV of the Sixteenth Annual Report of the Survey.

Fourteenth Annual Report, 1895. The rocks of the Sierra Nevada; by H. W. Turner. Washington, 1895. pp. 441–495. pls. 48–59.

—— The gold-silver veins of Ophir, California; by Waldemar Lindgren. pp. 249–284.

—— Tertiary revolution in the topography of the Pacific Coast; by J. S. Diller. pp. 403–433.

Fifteenth Annual Report, 1893–94.

Sketch of the geology of the San Francisco peninsula; by Andrew C. Lawson. pp. 399–476, pl. v–xii.

Sixteenth Annual Report, 1894–95.

Parts III and IV contain reports on mineral resources. Part IV contains reports on the production of coal in 1894, by F. W. Parker, pp. 1–217; Petroleum, by Joseph D. Weeks, pp. 315–404; Asphaltum, by E. W. Parker, pp. 430–435; Stone, by William C. Day, pp. 436–510; with reports on other minerals.

On the Quaternary and Recent mollusca of the Great Basin, with descriptions of new forms; by R. Ellsworth Call. Introduction is a sketch of the Quaternary lakes of the Great Basin, by G. K. Gilbert. Bulletin No. 11, Vol. 2. Washington, 1885. 56 pp. 6 plates.

On the Mesozoic and Cenozoic palæontology of California; by C. A. White. Bulletin No. 15, Vol. 3. Washington, 1885. 33 pp.

This report contains general remarks on the geology of the coast; the Shasta group; relations of the fauna of the auriferous slates to that of the Shasta group; the geological age of the *Aucella*-bearing strata of California; remarks on certain Californian fossils which have been identified with Eastern species; etc., etc.

Notes on the stratigraphy of California; by George F. Becker. Bulletin No. 19, Vol. 3. Washington, 1885. 28 pp.

This report treats of the metamorphic rocks of the Coast Ranges; the non-conformity between the Knoxville beds and the Chico; identity of the Mariposa and Knoxville beds; relation of the Cascades to the Sierra and the Coast Ranges of California; Mesozoic beds; Palæozoic rocks of California; etc.

On new Cretaceous fossils from California; by C. A. White. Bulletin No. 22, Vol. 3. Washington, 1885. 25 pp. 5 plates.

The following species are described in this bulletin: *Coralliochama*, n.gen; *C. Orcutti; Trochus (Oxystele) euryostomus; Nerita*, sp.?; *Cerithium Pillingi; C. totium; Sanctorum; Solarium Wallalensis.*

Notes on the geology of California; by J. S. Diller. Bulletin No. 33, Vol. 5. Washington, 1886. 23 pp.

This bulletin contains articles on the character and distribution of the Carboniferous limestones; structure of the Sierra Nevada range; age of the faulting of the Sierra Nevada range; age of the auriferous slates; general distribution of the metamorphic, volcanic, and Cretaceous rocks; relations of the Sierra, Coast, and Cascade ranges.

On invertebrate fossils from the Pacific Coast; by Charles A. White. Bulletin No. 51, Vol. 8, 1889, pp. 433–532, pls. 1–14. (Abstract Am. Geologist, Vol. 5, 1890, pp. 109–110.)

This paper contains: 1. New fossil mollusca from the Chico-Tejon series of California; 2. Equivalents of the Chico-Tejon series in Oregon and Washington; 3. Cretaceous fossils from Vancouver Island region; 4. Molluscan fauna of the Puget group; 5. Mesozoic mollusca from the southern coast of the Alaskan peninsula.

The earthquakes in California; by James E. Keeler. Bulletin No. 68. Washington, 1890. 25 pp.

Dictionary of altitudes in the United States (second edition); compiled by Henry Gannett. Bulletin No. 76. Washington, 1891. 393 pp.

ate volcanic eruption in Northern California, and its peculiar lava; by J. S. Diller. Bulletin No. 79. Washington, 1891. 33 pp. 17 plates.

'elation Papers: Cretaceous; by Charles A. White. Bulletin No. 82. Washington, 1891. 273 pp. 3 plates.

:elation Papers: Eocene; by W. B. Clark. Bulletin No. 83. Washington, 1891. 173 pp. 2 plates.

thquakes in California in 1890–91; by E. S. Holden. Bulletin No. 95. Washington, 1892.

thquakes in California in 1892; by C. D. Perrine. Bulletin No. 112. Washington, 1893.

'thquakes in California in 1893; by C. D. Perrine. Bulletin No. 114. Washington, 1894.

:thquakes in California in 1894; by C. D. Perrine. Bulletin No. 129. Washington, 1895.

ıtributions to the Cretaceous palæontology of the Pacific Coast. The fauna of the Knoxville beds; by Timothy W. Stanton. Bulletin No. 133. Washington, 1895. 85 pp., 20 plates.

This bulletin contains a definition of the Knoxville beds, geographic distribution, local developments in Tehama, Colusa, Lake, and Napa Counties, Mount Diablo, and other localities southward, etc., with descriptions of the following species:

BRACHIOPODA—*Rhynchonella Schucherti*, n.sp.; *R. Whitneyi*, Gabb; *Terebratella Californica*, n.sp.; *Terebratula*, sp.?

MOLLUSCA—*Ostrea*, sp.; *Anomia senescens*, n.sp.; *Spondylus fragilis*, n.sp.; *Lima multilineata*, n.sp.; *Pecten Californicus*, Gabb?; *P. complexicosta*, Gabb; *Avicula* (*Oxytoma*) *Whiteavesi*, n.sp.; *Aucella Piochi*, Gabb; *A. crassicollis*, Keyserl; *Inoceramus ovatus*, n.sp.; *Modiola major*, Gabb; *Myoconcha Americana*, n.sp.; *Pinna*, sp.?; *Arca Tehamaensis*, n.sp; *A. textrina*, n.sp.; *Pectunculus ? ovatus*, n.sp.; *Nucula Gabbi*, n.sp.; *N. Storrsi*, n.sp.; *Leda glabra*, n.sp.; *Cardiniopsis*, n.gen; *C. unioides*, n.sp.; *Solemya occidentalis*, n.sp.; *Astarte corrugata*, n.sp.; *A. Californica*, n.sp.; *A. trapezoidalis*, n.sp.; *Opis Californica*, n.sp.; *Lucina ovalis*, n.sp.; *L. Colusaensis*, n.sp.; *Cyprina occidentalis*, Whiteaves; *Solecurtus ? dubius*, n.sp.; *Corbula ? persulcata*, n.sp.; *C. filosa*, n.sp.; *Dentalium Californicum*, n.sp.; *Helcion' granulatus*, n.sp.; *Fissurella bipunctata*, n.sp.; *Pleurotomaria*, sp.?; *Turbo Paskentaensis*, n.sp.; *T. Wilburensis*, n.sp.; *T. trilineatus*, n.sp.; *T. Colusaenis*, n.sp.; *T. Morganensis*, n.sp.; *T. ? humerosus*, n.sp.; *Amberleya Dilleri*, n.sp.; *Atresius liratus*, Gabb; *Turritella*, sp.?; *Hypsipleura ? occidentalis*, n.sp.; *H. gregaria*, n.sp.;

On the Mesozoic and Cenozoic palaeontology
C. A. White. Bulletin No. 15, Vol. 3.
33 pp.

This report contains general remarks
the Shasta group; relations of the faun
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Bulletin No. 22, Vol. 3. W
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CIATION FOR THE ADVANCEMENT OF SCIENCE.

ed at Salem, Massachusetts.

Vol. 1, 1849—Vol. 43, 1896.

and probable geological age of the sandstone of San Francisco; by W. P. Blake. Proc. c. Adv. Sci., 9th Meeting, August, 1855, pp.

and polishing of hard rocks and minerals by d; by W. P. Blake. Proc. Amer. Assoc. Adv. h Meeting, August, 1855, pp. 216–220.

n the geology of California from observations in tion with the U. S. survey and explorations for a ad route to the Pacific; by W. P. Blake. Proc. r. Assoc. Adv. Sci., 9th Meeting, August, 1855, pp. -225.

the formation of mountains in the Sierra Nevada, alifornia; by John Muir. Proc. Amer. Assoc. Adv. Sci., 3d Meeting, at Hartford, 1874, pp. 49–64.

y Prof. Joseph LeConte, the retiring president of the sociation. Theories of the origin of mountain ranges. oc. Amer. Assoc. Adv. Sci., 42d Meeting, August, 1893.

mentary notes on the metamorphic series of the Shasta egion of California; by J. P. Smith. Proc. Amer. Assoc. Adv. Sci., 44th Meeting, August, 1896, pp. 137–138.

AMERICAN JOURNAL OF CONCHOLOGY.

Published at Philadelphia.

Vol. 1, 1865—Vol. 7, 1871.

Observations on certain Eocene fossils described as Cretaceous by Mr. W. M. Gabb in his report published in the Palæontology of California; by T. A. Conrad. Am. Jour. Conch., Vol. 1, 1865, pp. 362–365.

The author remarks that Mr. Gabb makes two divisions of his Cretaceous strata, A and B. The former is, doubtless, Cretaceous; and the latter, I am sure, will prove to be older Eocene. *Fusus Californicus*, Gabb, the author does not recognize as "my ? *Clavatula Californica*." *Volutilithes Navarroensis* belongs to "my genus *Rostellites*." *Fusus Rémondi* is a species of *Perissolax* allied to *P. penita*. *Amauropsis alveata* is a species of *Globularia*. *Fiscus mamillatus* is probably *Sycotypus modestus*, Conrad. *Perissolax* is a genus nearly related to *Sycotypus*. *Chemnitzia Spillmani* is very distinct from any species I described under that name. *Aturia Mathewsoni* is *Atuira zic-zac*. *Dosinia elevata* is *Dosineopsis alta*. *D. Uvasana* is *Dione ovata*, Rogers. *Meekia sella* is probably *Cyprina bisecta*. *M. navis* is a species of *Yoldia*. *Mactra Asburneri* is propbably *M. albaria*, Conrad. *Nucula truncata*—two species are evidently confounded under this name. *Leda protexta ?*—there are two species here united, neither of which is the *protexta*—one Eocene, the other Cretaceous.

A reply to these criticisms of Mr. Conrad is given by Mr. W. M. Gabb in the second volume, pp. 87–92.

Reply to Mr. Conrad's criticism on Mr. Gabb's report on the Palæontology of California; by W. M. Gabb. Am. Jour. Conch., Vol. 2, 1866, pp. 87–92.

Further observations on Mr. Gabb's Palæontology of California; by T. A. Conrad. Am. Jour. Conch., Vol. 2, 1866, pp. 97–100.

The author remarks that *Volutilithes Navarroensis* has the external sculpture and form of a species of *Rostellites* found in New Jersey. *Perissolax*, Gabb, is limited to one species, but it is very different from *Busycon Blakei*, Conrad. *Hemifusus Horni*, *H. Cooperi*, and *H. Rémondi*, Gabb, and *Fusus mamillatus*, Gabb, are members of my proposed genus *Ficopsis*. *Amauropsis alveata*, Gabb, is a member of Lamarck's genus *Ampullina*. *Venericardia Horni*, Gabb, is a very different variety from the *V. planicosta*. *Hamites Vancouverensis* I believe to be an *Ancyloceras*. *Ptycoceras æquicostatus* is more likely to be *Hamites*. *Neptunea curvirostris* I believe to represent an undescribed genus.

The controversy which, for a long time, was maintained between Conrad and Gabb as to the age of the Tejon rocks of California,

referred by Conrad to the Eocene and by Gabb to represent the uppermost member of the Cretaceous (Division B of the California Reports), can be found in the following papers:

Conrad. Am. Jour. of Conchology, Vol. I (1865), pp. 362-5; Vol. II (1866), pp. 97-100; Am. Jour. Sci., Vol. XLIV (1867), pp. 376-7.

Gabb. Am. Jour. of Conchology, Vol. II (1866), pp. 87-92; Am. Jour. Sci., Vol. XLIV (1867), pp. 266-9; Proc. Cal. Acad. Nat. Sciences, Vol. III (1867), pp. 301-306.

Heilprin, in his article on the age of the Tejon rocks, etc., Proc. Acad. Nat. Sci., Phila., 1882, p. 196, remarks, in a footnote, "that Conrad finally yielded his position, but he has been unable to discover the evidence of such a change of opinion in any of that author's writings."

Descriptions of some secondary fossils from the Pacific States; by W. M. Gabb. Amer. Jour. Conch., Vol. 5, 1870, pp. 5–18, pls. 3–7.

Orthoceras Blakei, Gabb; *Ammonites Nevadanus*, Gabb; *A. Colfaxi*, Gabb; *A. Billingsianus*, Gabb?; *Turbo regius*, Gabb?; *T. elevatus*, Gabb; *Pholadomya multilineata*, Gabb; *P. Nevadana*, Gabb; *Goniomya aperta*, Gabb; *Myacites depressus*, Meek; *Cardium arcæformis*, Gabb; *Astarte appressa*, Gabb; *Cardinia ponderosa*, Gabb; *Posidonomya Blatchleyi*, Gabb; *Pinna*, sp.; *Crassianella lingulata*, Gabb; *Lima* (*Plagiostoma*), sp. undt.; *Monotis circularis*, Gabb; *Pecten acutiplicatus*, Meek; *Plicatula perembricata*, Gabb; *Spirifer obtusus*, Gabb.

The author publishes the opinion that all the Jurassic deposits of the Sierra Nevada and their vicinity were probably of Triassic age. (page 5.)

THE AMERICAN NATURALIST.

Published in Philadelphia.

Remarks on fossil shells from the Colorado Desert; by Robert E. C. Stearns. Am. Nat., Vol. 13, No. 3, March, 1879.

The author illustrates *Physa humerosa*, Gould; *Tryonia protea*, and varieties semi-fossil from Colorado Desert, California; *Anodonta Californiensis*, Lea; *Amnicola longinqua*, Gould; *Anondonta*, Owens River, Cal.; *Anodonta*, Bear River, Utah.

Mountain upthrusts; by C. A. White. Am. Nat., Vol. 22, 1888, pp. 399-408.

Notes on the glaciation of Pacific Coast; by G. F. Wright. Am. Nat., Vol. 21, 1887, pp. 250–256.

Mesozoic and Cenozoic realms in North America; by E. D. Cope. Am. Nat., Vol. 21, 1887, pp. 445–462.

Across the Santa Barbara Channel; by J. Walter Fewkes. Am. Nat., Vol. 33, 1889, pp. 211–217, 387–394.

Includes references to some geologic features and history of Santa Cruz Island, and the origin of some sandstone bowlders near Santa Barbara.

INTERNATIONAL CONGRESS OF GEOLOGISTS, AMERICAN COMMITTEE REPORTS, 1888.

On nomenclature of Cenozoic formations; by Joseph LeConte. International Congress of Geologists, American Committee Reports, 1888, pp. 17–18; American Geologist, Vol. 2, 1888, pp. 283–284.

Reference to the nomenclature of the Tertiary and the position of Cenozoic unconformity in California.

THE AMERICAN GEOLOGIST.

Published at Minneapolis, Minn.

Vol. 1, 1888—Vol. 17, 1896.

Flora of coast islands of California, in relation to recent changes of physical geography; by Joseph LeConte. Am. Geol., Vol. 1, 1888, pp. 76–81.

Lavas of Northern California; by J. S. Diller. Am. Geol., Vol. 1, 1888, pp. 125–126. (From Am. Jour. Sci., Jan., 1887, Vol. 33, pp. 45–50.)

Describes beds of volcanic ash in place, inclosing the stumps of more or less decayed trees, the nature, origin, and occurrence of which is discussed at length.

Effects of pressure of a continental glacier; by A. Winchell. Am. Geol., Vol. 1, 1888, pp. 139–143.

The views here enunciated were published in the University *Argonaut*, in March, 1886.

Glacial action on flanks of higher Sierra Nevada. Am. Geol., Vol. 3, 1889, pp. 340–341.

This is an editorial note of the glacial planing on Upper and Lower Sardine Lakes, near Young America Mine.

Notes on the geology and scenery of the islands forming the southern line of the Santa Barbara Channel; by Dr. L. G. Yates. Am. Geol., Vol. 5, 1890, pp. 43–52.

Geology of the Mother Lode gold belt; by H. W. Fairbanks. Am. Geol., Vol. 7, 1891, pp. 209–222.

The pre-Cretaceous age of the metamorphic rocks of the California Coast Range; by H. W. Fairbanks. Am. Geol., Vol. 9, 1892, pp. 153–166.

Notes on a further study of the pre-Cretaceous rocks of the California Coast Ranges; by H. W. Fairbanks. Am. Geol., Vol. 11, 1893, pp. 69–84. plate.

Some recent contributions to the geology of California; by H. W. Turner. Am. Geol., Vol. 11, 1893, pp. 307–324.

Geological notes on the Sierra Nevada, Part 1; by H. W. Turner. Am. Geol., Vol. 13, 1894, pp. 228–249.

Geological notes on the Sierra Nevada, Part 2; by H. W. Turner. Am. Geol., Vol. 13, 1894, pp. 297–316.

Notes on some localities of Mesozoic and Palæozoic, in Shasta County, California; by H. W. Fairbanks. Am. Geol., Vol. 14, 1894, pp. 25–31.

This report contains notes on the Trias of Squaw Creek, the Carboniferous of the McCloud River, and the Devonian of the Sacramento River, near Kennett Station.

Notes on the geology of the Coast Ranges of California; by H. W. Turner and T. W. Stanton. Am. Geol., Vol. 14, 1894, pp. 92–98.

A contribution to the geology of the Coast Ranges; by Andrew C. Lawson. Am. Geol., Vol. 15, 1895, pp. 342–356.

Auriferous gravels of the Sierra Nevada; by H. W. Turner. Am. Geol., Vol. 15, 1895, pp. 371–379.

Notes on the geology of Eastern California; by Harold W. Fairbanks. Am. Geol., Vol. 17, 1896, pp. 63–74.

The mineral deposits of Eastern California; by Harold W. Fairbanks. Am. Geol., Vol. 17, 1896, pp. 144–158.

AMERICAN JOURNAL OF SCIENCE AND ARTS.

Published at New Haven, Conn.

1st series: Vol. 1, 1819—Vol. 50, 1845.
2d series: Vol. 1, 1846—Vol. 50, 1870.
3d series: Vol. 1, 1871—Vol. 50, 1896.

California, elevation of, during the Tertiary epoch; by T. A. Conrad. Am. Jour. Sci., 1st ser., Vol. 35, 1839, p. 245.

In the author's article, "Notes on American Geology," in this journal, the author remarks: "On the coast of California Mr. Nuttall found shells of recent species two hundred feet above the sea. These are so much more remote from the axis of elevation than the Tertiary shell of New York that the uplift of the Rocky Mountains must have been far greater during the upper Tertiary period than was any part of the Atlantic chain."

Fossil shells from the Tertiary deposits on the Columbia River, near Astoria; by T. A. Conrad. Am. Jour. Sci., 2d ser., Vol. 5, 1848, pp. 432–433. 14 woodcuts.

The author describes and figures the following fossils, principally from cement-stone bowlders at Astoria, Oregon: *Nucula devaricata*, n.sp.; *N. cuneiformis*, n.sp.; *N. abrupta*, n.sp.; *Mactra albaria*, n.sp.; *Tellina Oregonensis*, n.sp.; *T. obruta*, n.sp.; *Loripes parilis*, n.sp.; *Cytherea Oregonensis*, n.sp.; *C. vespertina*, n.sp.; *Nucula penita*, n.sp.; *Bullina petrosa*, n.sp.; *Pyrula modesta*, n.sp.; *Fusus Oregonensis*, n.sp.; *Solen curtus*, n.sp.

The following species were collected by the writer at Astoria, and sent to the American Museum at New York. As the list is unpublished, it may be well to include it as a note to Mr. Conrad's paper: *Nucula devaricata*, Con.; *N. impressa*, Con.; *Tellina albaria*, Con.; *Solemya ventricosa*, Con.; *Pecten propatulus*, Con.; *Area devincta*, Con.; *Venus bisecta*, Con.; *Pectunculus nitens*, Con.; *Venus angustifrons*, Con.; *Tellina emacerata*, Con.; *T. arctata*, Con.; *Lucina aculitmeata*, Con.; *Cardita sublenta*, Con.; *Terebratula nitens*, Con.; *Dolium petrosium*, Con.; *Rostellaria indurata*, Con.; *Fusus geniculus; Sigeretus* (*Lumatia*) *scopulosa; Teredo substriatus; A dentalium; Naulitus angulatus*, Con. Besides these there are three or four species of bivalves and four of Gasteropods, undetermined, and one Brachipod. These fossils were collected from the cement stones and argillaceous shales; all belong to one geological period, as the same species are found in each to some extent, though most are different.

Mines of cinnabar in Upper California; by C. S. Lyman. Am. Jour. Sci., 2d ser., Vol. 6, 1848, pp. 270–271.

Gold in California. Amer. Jour. Sci., 2d ser., Vol 7, 1848, pp. 125 and 262.

Notes on Upper California, by James D. Dana, from observations made during the cruise of the U. S. exploring expedition, under Capt. Charles Wilkes, U. S. N. Am. Jour. Sci., 2d ser., Vol. 7, 1848, pp. 247–264.

Observations on California; by Rev. C. S. Lyman. Am. Jour. Sci., 2d ser., 1848, p. 291, also 305 and 307.

Platinum and diamonds in California. Am. Jour. of Sci., 2d ser., Vol. 7, 1848, p. 294.

California gold region; by Rev. C. S. Lyman. Am. Jour. Sci., 2d ser., Vol. 8, 1849, p. 415.

Gold of California; by Rev. C. S. Lyman. Am. Jour. Sci., 2d ser., Vol. 9, 1849, p. 126.

Observations on the Pluton geysers of California; by Forest Shepherd. Am. Jour. Sci., 2d ser., Vol. 12, 1851, pp. 153–158.

On the Diluvial or Quaternary deposits in California; by James Blake. Am. Jour. Sci., 2d ser., Vol. 13, 1852, pp. 385–391.

Notes on the Almaden mine, California; by T. S. Hart. Am. Jour. Sci., 2d ser., Vol. 16, 1853, pp. 137–139.

Infusoria of California. Ehrenberg (Monatsb. d. k. Pr. Akad. Wiss., Berlin, Aug., 1852, p. 528) gives the list published in Am. Jour. Sci., 2d ser., Vol. 16, 1853, p. 134.

On some new localities of fossil Diatomaceæ in California; by J. W. Bailey. Am. Jour. Sci., 2d ser., Vol. 17, 1854, pp. 179–180.

Quicksilver mines of Almaden, California; by W. P. Blake. Am. Jour. Sci., 2d ser., Vol. 17, 1854, pp. 438–440.

Recent earthquake shocks in California. Letter of W. P. Blake, in Am. Jour. Sci., 2d ser., Vol. 17, 1854, p. 151.

Account of some volcanic springs in the Desert of the Colorado, in Southern California; by John L. Le Conte. Am. Jour. Sci., 2d ser., Vol. 18, 1855, pp. 1–6.

Observations on the extent of the gold regions of California and Oregon, with notices of mineral localities in California and some remarkable specimens of crystalline gold; by W. P. Blake. Am. Jour. Sci., 2d ser., Vol. 20, 1855, pp. 72–85.

Earthquakes in California during the year 1856; by Dr. J. B. Trask. Am. Jour. Sci., 2d ser., Vol. 23, 1857, pp. 341–346.

Fossil plants of recent formations; by Leo Lesquereux. Am. Jour. Sci., 2d ser., Vol. 27, 1859, pp. 359–363.

On the direction and velocity of the earthquake, in California, of January 9, 1857; by John B. Trask. Am. Jour. Sci., 2d ser., Vol. 25, 1858, pp. 146–148.

Progress of the Geological Survey of California; by J. D. Whitney. Am. Jour. Sci., 2d ser., Vol. 38, 1864, pp. 256–264.

Notes on the New Almaden quicksilver mines; by B. Silliman, Jr. Am. Jour. Sci., 2d ser., Vol. 38, 1864, pp. 190–194.

Notice of the explorations of the Geological Survey of California, in the Sierra Nevada, during the summer of 1864; by J. D. Whitney. Am. Jour. Sci., 2d ser., Vol. 39, 1865, pp. 10–13.

Petroleum in California; by B. Silliman, Jr. Am. Jour. Sci., 2d ser., Vol. 39, 1865, p. 101, also p. 341.

On the deep placers of the South and Middle Yuba, Nevada County, California, in connection with the Middle Yuba and Eureka Lake Canal Companies; by B. Silliman, Jr. Am. Jour. Sci., 2d ser., Vol. 40, 1865, pp. 1–19.

On the borax in California; by J. D. Whitney. Am. Jour. Sci., 2d ser., Vol. 41, 1866, pp. 255–258.

Alleged discovery of an ancient skull in California; by W. H. B. Am. Jour. Sci., 2d ser., Vol. 42, 1866, p. 424.

On the naphtha and illuminating oil from heavy California tar (maltha); by B. Silliman, Jr. Am. Jour. Sci., 2d ser., Vol. 43, 1867, pp. 242–246.

Note upon the occurrence of fossil remains of the tapir in California; by W. P. Blake. Am. Jour. Sci., 2d ser., Vol. 45, 1868, p. 381.

The remains of a tapir occur in the auriferous gravel of Wood's Creek, near Sonora, Tuolumne County.

Reply to Mr. Gabb on the Cretaceous rocks of California; by T. A. Conrad. Am. Jour. Sci., 2d ser., Vol. 44, 1867, pp. 376–377.

On the subdivisions of the Cretaceous rocks of California; by W. M. Gabb. Am. Jour. Sci., 2d ser., Vol. 44, 1867, pp. 226–229.

On human remains along with those of the mastodon in the drift of California; by Dr. C. F. Winslow. Am. Jour. Sci., 2d ser., Vol. 46, 1868, p. 407.

Notes on the chemical geology of the gold fields of California; by J. Arthur Phillips. (Proc. Roy. Soc., Vol. XVI, p. 294.) Am. Jour. Sci., 2d ser., Vol. 47, 1869, pp. 134–139.

On the supposed absence of northern drift from the Pacific Slope of the Rocky Mountains; by Dr. Robert Brown. Am. Jour. Sci., 2d ser., Vol. 50, 1870, pp. 318–324.

On the discovery of actual glaciers on the mountains of the Pacific Slope; by Clarence King. Am. Jour. Sci., 3d ser., Vol. 1, 1871, pp. 157–167.

Notice of a fossil forest in the Tertiary of California; by O. C. Marsh. Am. Jour. Sci., 3d ser., Vol. 1, 1871, pp. 266–268.

On the Owen's Valley earthquake; by J. W. Whitney. Am. Jour. Sci., 3d ser., Vol. 4, 1872, pp. 316–318. (From the Overland Monthly, August and September numbers, 1872.)

LE CONTE, JOSEPH. Theory of formation of great features of the earth's surface. Am. Jour. Sci., 3d ser., Vol. 4, 1872, pp. 345–460.

—— Note in Vol. 5, 1873, p. 156.

—— Reply to Prof. T. Sterny Hunt. Vol. 5, 1873, p. 448.

On some of the ancient glaciers of the Sierras; by Joseph Le Conte. Am. Jour. Sci., 3d ser., Vol. 5, 1873, pp. 325–342. map.

On the Klamath River mines: remarkable gravel deposits of the Lower Klamath—a sketch of their geology; by A. W. Chase. Am. Jour. Sci., 3d ser., Vol. 6, 1873, pp. 56–59.

On the great lava-flood of the West, and on the structure and age of the Cascade Mountains; by Joseph Le Conte. Am. Jour. Sci., 3d ser., Vol. 7, 1874, pp. 167–180; also pp. 259–267. See also Proc. Cal. Acad. Sci., Vol. 5, 1873, p. 214.

On the auriferous gravel deposits of Gold Bluff; by A. W. Chase. Am. Jour. Sci., 3d ser., Vol. 7, 1874, pp. 379–384.

On the probable existence of microscopic diamonds, with zircons and topaz, in the sands of hydraulic washings in California; by B. Silliman. Am. Jour. Sci., 3d ser., Vol. 5, 1873, pp. 384–385; see also p. 133 of Vol. 6.

On actual glaciers in California; by John Muir. Am. Jour. Sci., 3d ser., Vol. 5, 1873, pp. 69–71. (From the Overland Monthly for December, 1872.)

On mountain sculpture in the Sierra Nevada, and the method of glacial erosion; by E. S. Carr. Am. Jour. Sci., 3d ser., Vol. 7, 1874, pp. 515–516. (From the Overland Monthly for May, 1874.)

Ancient glaciers of Sierra Nevada in Lake Valley; by J. Le Conte. Am. Jour. Sci., 3d ser., Vol. 10, 1875, p. 126. See also Proc. Cal. Acad Sci., Vol. 5, 1873.

On the evidence of horizontal crushing in the formation of the Coast Range of California; by Joseph Le Conte. Am. Jour. Sci., 3d ser., Vol. 11, 1876, pp. 297–304.

Formation of Coast Ranges; by J. Le Conte. Am. Jour. Sci., 3d ser., Vol. 11, 1876, p. 297.

The age of the Tejon group, California; by Dr. J. G. Cooper. Am. Jour. Sci., 3d ser., Vol. 14, 1877, p. 321. (From Proc. Cal. Acad. Sci., Nov. 16, 1874.)

On the structure and origin of mountains, with special reference to recent objections to the contraction theory; by Joseph Le Conte. Read before the National Academy of Science. Am. Jour. Sci., 3d ser., Vol. 16, 1878, pp. 95–112.

Volcanoes about Lake Mono, and their relation to the glacier drifts; by Joseph Le Conte. Am. Jour. Sci., 3d ser., Vol. 18, 1879, pp. 35–44.

The relation of secular rock disintegration to Lœss glacial drift and rock basins; by Raphael Pumpelly. Am. Jour. Sci., 3d ser., Vol. 17, 1879, pp. 138–144.

See note on p. 139, regarding California rocks.

Mono volcanoes, and relation to glacial epoch; by Joseph Le Conte. Am. Jour. Sci., 3d ser., Vol. 18, 1879, p. 79.

The old river-beds of California; by Joseph Le Conte. Am. Jour. Sci., 3d ser., Vol. 19, 1880, pp. 176–190.

Origin of jointed structure in undisturbed clay and marl deposits; by John Le Conte. Am. Jour. Sci., 3d ser., Vol. 23, 1882, pp. 233–234.

The phenomena of metalliferous vein formation now in progress at Sulphur Bank, California; by Joseph Le Conte and W. B. Rising. Am. Jour. Sci., 3d ser., Vol. 24, 1882, pp. 23–33.

The relations of the mineral belts of the Pacific Slope to the great upheavals; by George F. Becker. Am. Jour. Sci., 3d ser., Vol. 28, 1884, pp. 209–212.

The geometrical form of volcanic cones and elastic limit of lava; by George F. Becker. Am. Jour. Sci., 3d ser., Vol. 30, 1885, pp. 283–293.

On mineral vein formation now in progress at Steamboat Springs, compared with some at Sulphur Bank; by Joseph Le Conte. Am. Jour. Sci., 3d ser., Vol. 25, 1883, pp. 424–428.

On the genesis of metalliferous veins; by Joseph Le Conte. Am. Jour. Sci., 3d ser., Vol. 26, 1883, pp. 1–19.

On origin of bitumen; by S. F. Peckham. Am. Jour. Sci., 3d ser., Vol. 28, 1884, pp. 105–117.

Cretaceous metamorphic rocks of California; by George F. Becker. Am. Jour. Sci., 3d ser., Vol. 31, 1886, pp. 348-357.

A Post Tertiary elevation of the Sierra Nevada, shown by the river-beds; by Joseph Le Conte. Am. Jour. Sci., 3d ser., Vol. 32, 1886, pp. 167–181.

Notes on the geology of Northern California; by J. S. Diller. (Abstract of paper from the Proc. Phil. Soc. of Washington.) Am. Jour. Sci., 3d ser., Vol. 33, 1887, pp. 152–153.

The latest volcanic eruption in Northern California, and its peculiar lava; by J. S. Diller. Am. Jour. Sci., 3d ser., Vol. 33, 1887, pp. 45–50.

The texture of massive rocks; by George F. Becker. Am. Jour. Sci., 3d ser., Vol. 33, 1887, pp. 50–58. (Abstract from Popular Science Monthly, Vol. 31, 1887, pp. 425–426.)

Discusses the relation of texture in igneous rocks to the conditions under which they were cooled, etc. The author also restates his conclusions in regard to the disputed age and relations of the Washoe rocks.

The flora of the coast islands of California, in relation to recent changes of physical geography; by Joseph Le Conte. Am. Jour. Sci., 3d ser., Vol. 34, 1887, pp. 457–460. See also, Cal. Acad. Sci. Bull., Vol. 2, 1887, pp. 515–520; Am. Geol., Vol. 1, 1888, pp. 76–81; Nature, Vol. 37, 1887, p. 358.

A discussion of the Post Tertiary physical changes of the coast region of California, as indicated by the flora and fauna of the coast islands.

On the occurrence of Hanksite in California; by Henry G. Hanks. Am. Jour. Sci., 3d ser., Vol. 37, 1889, pp. 63–66.

On the origin of normal faults and the structure of the basin region; by Joseph Le Conte. Am. Jour. Sci., 3d ser., Vol. 38, 1889, pp. 257–263.

Origin and mechanism of faults, especially those of the Great Basin.

Notes on the Cretaceous rocks of Northern California; by J. S. Diller. Am. Jour. Sci., 3d ser., Vol. 40, 1890, pp. 476–478.

The validity of the so-called Wallala beds as a division of the California Cretaceous; by H. W. Fairbanks. Am. Jour. Sci., 3d ser., Vol. 45, 1893, pp. 473–478.

Discovery of Devonian rocks in California; by J. S. Diller and Charles Schuchert. Am. Jour. Sci., 3d ser., Vol. 47, 1894, pp. 416–422.

An auriferous conglomerate of Jurassic age from the Sierra Nevada; by W. Lindgren. Am. Jour. Sci., 3d ser., Vol. 48, 1894, pp. 275–280.

Lower Cambrian rocks in Eastern California; by Chas. D. Walcott. Am. Jour. Sci., 3d ser., Vol. 49, 1895, pp. 141–144.

Some reptilian remains from the Triassic of Northern California; by J. C. Merriam. Am. Jour. Sci., 3d ser., Vol. 50, 1895, pp. 55–57.

The author describes the saurian remains of two individuals from black Triassic limestone of Shasta County under the name of *Shastasaurus pacificus*, n. gen. et sp. nov.

THE AMERICAN MINING GAZETTE.

Published at New York City.

Gold; its discovery and progressive development in the United States. Am. Min. Gazette, Vol. 1, 1864, pp. 221–235.

The Mariposa estate. Am. Min. Gazette, Vol. 1, 1864, p. 431.

ANNALS OF THE NEW YORK LYCEUM OF NATURAL HISTORY.

Published at New York City.

1st Series: Vol. 1, 1824—Vol. 11, 1876.

Catalogue of shells collected at Panama, with notes on synonymy, station, and habitat; by C. B. Adams. Ann. N. Y. Lyceum of Nat. Hist., Vol. V, 1852, pp. 229–548. (Also published separately.)

The author gives full notes and descriptions, but no illustrations. Out of nearly 500 species, over 100 were new; but few of them extend to California, though many of the species are found living or fossil farther north.

BULLETINS OF THE GEOLOGICAL SOCIETY OF AMERICA.

Vol. 1, 1890—Vol. 6, 1894.

Orographic movements of the Rocky Mountains; by S. F. Emmons. Bull. Geol. Soc. of America, Vol. 1, pp. 245–286. April 7, 1890.

Sandstone dikes; by J. S. Diller. Bull. Geol. Soc. of America, Vol. 1, pp. 411–442, pls. 6–8. April 21, 1889.

The structure of a portion of the Sierra Nevada of California; by George F. Becker. Bull. Geol. Soc. of America, Vol. 2, pp. 49–74. January 10, 1891.

Antiquities from under Tuolumne Table Mountain in California; by George F. Becker. Bull. Geol. Soc. of America, Vol. 2, pp. 189–200, pl. 7. February 20, 1891.

Notes on the Early Cretaceous of California and Oregon; by George F. Becker. Bull. Geol. Soc. of America, Vol. 2, pp. 201–208. February 20, 1891.

Tertiary and Post Tertiary changes of the Atlantic and Pacific Coasts, with a note on the mutual relations of land elevation and ice accumulation during the Quaternary

period; by Joseph Le Conte. Bull. Geol. Soc. of America, Vol. 2, pp. 323–330. March 16, 1891.

The geology of Mount Diablo, California; by H. W. Turner. With a supplement on the chemistry of the Mount Diablo rocks; by W. H. Melville. Bull. Geol. Soc. of America, Vol. 2, pp. 383–414; pl. 15. March 30, 1891.

Geology of the Taylorville region of California; by J. S. Diller. Bull. Geol. Soc. of America, Vol. 3, pp. 369–394. July 15, 1892.

Jura and Trias at Taylorville, California; by Alpheus Hyatt. Bull. Geol. Soc. of America, Vol. 3, pp. 395–412. July 15, 1892.

Stratigraphy and succession of the rocks of the Sierra Nevada of California; by James E. Mills. Bull. Geol. Soc. of America, Vol. 3, pp. 413–444, pl. 13. August 8, 1892.

Cretaceous and Early Tertiary of Northern California and Oregon; by J. S. Diller. Bull. Geol. Soc. of America, Vol. 4, pp. 205–224, pl. 4. April 14, 1893.

The faunas of the Shasta and Chico formations; by T. W. Stanton. Bull. Geol. Soc. of America, Vol. 4, pp. 245–266. June 8, 1893.

Two Neocene rivers of California; by W. Lindgren. Bull. Geol. Soc. of America, Vol. 4, pp. 257–298, pl. 5–9. June 19, 1893.

Age of the auriferous slates of the Sierra Nevada; by James P. Smith. Bull. Geol. Soc. of America, Vol. 5, pp. 243–258. February 27, 1894.

Trias and Jura in the Western States; by Alpheus Hyatt. Bull. Geol. Soc. of America, Vol. 5, 1894, pp. 395–434.

The author places the relative age of the rocks of California, in different localities, as follows:

Trias—American and Sailor's Cañons.

Lower Jura—Inyo County, Cal.; Taylorville, Cal.

Middle Jura—Taylorville, Cal.

Upper Jura—Taylorville, Cal.; Mariposa Basin. Cal.; Colfax Basin, Cal.

The following new species of fossils are described, but not figured: From American Cañon: *Monotis semplicata; M. symmetrica.*

From Sailor's Cañon: *Daonella? subjecta; D. böchiformis; D. cardinoides; Hemientolium?* sp.?; *Panopea?* sp.?; *Entolium* sp.?; *Gryphæa* sp.?

Upper Jura fossils of the gold belt slates: *Cardioceras dubium,* Texas Ranch, Calaveras County; *Perisphinctes virgulatiformis,* near Reynolds Ferry; *Perisphinctes* sp.?, the same; *P. filiplex?,* Quenstedt, Tuolumne River, etc.; *P. Colfaxi,* Gabb, one mile west of Colfax; *P. Mühbachi,* El Dorado County; *Olcostephanus Lindgreni,* near Colfax; *Oecotrautes denticulata,* Stanislaus River; *Belemnites Pacificus,* Gabb, Mariposa County, American Cañon; *Avicula* sp.?, Stanislaus River; *Amusium aurarium,* Meek, six miles from Copperopolis; *Aucella Erringtoni,* Meek, var. *arcuata,* Tuolumne River, etc.; *A. elongata,* Stanislaus River; var. *Elongata orbicularis, A. aviculæformis,* near Reynolds Ferry; var. *acuta,* six miles from Copperopolis; *A. orbicularis,* Calaveras County.

The Shasta-Chico series; by J. S. Diller and T. W. Stanton. Bull. Geol. Sci. of America, Vol. 5, pp. 435–464. April 12, 1894.

The authors give the following conclusions: That the discovery of *Coralliochama Orcutti,* in the basal portion of the Chico beds, in the Sacramento Valley, demonstrates that the Wallala beds are only a phase of the Chico. The Shasta-Chico series is composed of the Knoxville, Horsetown, and Chico beds, which are each characterized by its own fauna. The fauna of adjacent beds, however, are so bound together by many common species that there is no palæontologic break. The Mariposa and Knoxville beds are faunally distinct and unconformable; the former Jurassic, and the latter Cretaceous.

Geological sketch of Lower California; by S. F. Emmons and G. P. Merrill. Bull. Geol. Soc. of America, Vol. 5, pp. 489–514, pl. 19. April 21, 1894.

Review of our knowledge on the geology of the California coast ranges; by H. W. Fairbanks. Bull. Geol. Soc. of America, Vol. 6, pp. 71–102. December 24, 1894.

Characteristic features of California gold-quartz veins; by W. Lindgren. Bull. Geol. Soc. of America, Vol. 6, pp. 221–240, pl. 11. March 5, 1895.

CALIFORNIA ACADEMY OF SCIENCES.

Published at San Francisco, Cal.

Memoirs: Vol. 1, 1868—Vol. 2, 1895.
Bulletins: Vol. 1, 1884—Vol. 2, 1886–87.
Occasional Papers: Nos. 1–4, 1890–95.
Proceedings, 1st series: Vol. 1, 1854—Vol. 7, 1876.
Proceedings, 2d series: Vol. 1, 1888—Vol. 6, 1896.

The natural system of volcanic rocks; by F. Baron Richthofen. Memoirs Cal. Acad. Sci., Vol. 1, Part 2. San Francisco, 1868. 95 pp.

The following is the classification of volcanic rocks:
Order First: Rhyolite—
Family 1. Nevadite, or granitic rhyolite.
2. Liparite, or porphyritic rhyolite.
3. Rhyolite proper, or lithoidic and hyaline rhyolite.
Order Second: Trachyte—
Family 1. Sanidin trachyte.
2. Oligoclase trachyte.
Order Third: Propylite—
Family 1. Quartzose propylite.
2. Hornblendic propylite.
3. Augitic propylite.
Order Fourth: Andesite—
Family 1. Hornblendic andesite.
2. Augitic andesite.
Order Fifth: Basalt—
Family 1. Dolerite.
2. Basalt.
3. Leucitophyre.

On certain fossils from San Luis Obispo County; by Dr. Antisell. Proc. Cal. Acad. Sci., Vol. 1, 1854–57, pp. 34–35.

Description of *Ammonites Batesi;* by Dr. J. B. Trask. Proc. Cal. Acad. Sci., Vol. 1, 1854–57, p. 39.

Descriptions of fossil shells; by Dr. J. B. Trask. Proc. Cal. Acad. Sci., Vol. 1, 1854–57, pp. 40–42.

Chemnitzia papillosa, n.sp.; *Tornatella elliptica*, n.sp.; *Murex fragilis*, n.sp.; *Fusus Barbarensis*, n.sp.; *F. robustus*, n.sp.; *F. rugosus*, n.sp.

On the cause of tides, earthquakes, rising of continents, etc.; by Dr. C. F. Winslow. Proc. Cal. Acad. Sci., Vol. 1, 1854–57, pp. 48–51.

Remarks on certain geological specimens; by Horace Davis. Proc. Cal. Acad. Sci., Vol. 1, 1854–57, p. 62.

Report on mineral waters from Red Bluff; by Dr. Lanszweert. Proc. Cal. Acad. Sci., Vol. 1, 1854–57, pp. 72–74.

On earthquakes in California from 1812–1857; by Dr. J. B. Trask. Proc. Cal. Acad. Sci., Vol. 1, 1854–57, pp. 85, 102, 109, and 121.

Republished Am. Jour. Sci, 2d ser., Vol. 22, 1856, pp. 110–116.

Description of new species of Ammonite and Baculite; by Dr. J. B. Trask. Proc. Cal. Acad. Sci., Vol. 1, 1854–57, p. 92.

Ammonite Chicoensis, n.sp.; *Baculite Chicoensis*, n.sp.

Description of three new species of the genus Plagiostoma from the Cretaceous rocks of Los Angeles; by Dr. J. B. Trask. Proc. Cal. Acad. Sci., Vol. 1, 1854–57, pp. 93–94, pl. 3.

Plagiostoma Pedroana, n.sp.; *P. annulatus*, n.sp.; *P. truncata*, n.sp.

On the mud volcanoes in the Colorado Desert; by Dr. John A. Veatch. Proc. Cal. Acad. Sci., Vol. 1, 1854–57, pp. 116–120.

Republished Am. Jour Sci., 2d ser., Vol. 26, 1858, p. 288.

The Proceedings of the California Academy of Sciences included in Vol. 1 were originally printed in "The Pacific," a newspaper published in San Francisco. This volume was afterward published by the Academy in two editions.

Earthquakes in California in 1858–59; by Dr. J. B. Trask. Proc. Cal. Acad. Sci., Vol. 2, 1858–62, pp. 38–39.

Description of two new species of bivalved shell from the Tertiaries of Contra Costa County; by A. Rémond. Proc. Cal. Acad. Sci., Vol. 3, 1863–68, p. 13.

Cardium Gabbi, n.sp.; *Ostrea Bourgeoisi*, n.sp.

Description of four new species of Echinodermata from the Tertiaries of Contra Costa County; by A. Rémond. Proc. Cal. Acad. Sci., Vol. 3, 1863, pp. 52–53.

Astrodapsis Whitneyi, n.sp.; *A. tumidus*, n.sp.; *Echinarachnius Brewerianus*, n.sp.; *Clypeaster Gabbi*, n.sp.

Earthquakes in California from 1800–1864; by John B. Trask. Proc. Cal. Acad. Sci., Vol. 3, 1863–68, pp. 130–144.

For articles on same subject, see p. 190; also, p. 239.

Notes on some fossils from the gold-bearing slates of Mariposa, with description of some new species; by W. M. Gabb. Proc. Cal. Acad. Sci., Vol. 3, 1863–68, pp. 172–173.

Lima Erringtoni; Pholadomya orbiculata; Belemnites Pacificus.

Communication on the San Luis Obispo quicksilver fossils; by W. M. Gabb. Proc. Cal. Acad. Sci., Vol. 3, 1863–68, p. 173.

New mineral oil regions in the Tulare Valley; by William P. Blake. Proc. Cal. Acad. Sci., Vol. 3, 1863–68, p. 193.

Notice of a human skull recently taken from a shaft near Angels, Calaveras County; by J. D. Whitney. Proc. Cal. Acad. Sci., Vol. 3, 1863–68, pp. 277–279.

See also "The Pacific," Vol. XVIII, No. 48; Congregationalist, September 27, 1876, and Rev. des Deux Mondes, Vol. XII, 3d ser., p. 288.

Miscellaneous notices; by William P. Blake. Proc. Cal. Acad. Sci., Vol. 3, 1863–68, pp. 289–291.

1. New locality of fossils, in the gold-bearing rocks of California.
2. Tooth of the extinct elephant, Placer County.
3. Shark teeth and other remains, Tulare County.
4. Quarry of gold-bearing rocks.

This volume contains also other short notices on fossils from Mare Island, Oregon Bar, Mariposa, etc., with mineralogical notices.

On the subdivisions of the Cretaceous formation in California; by W. M. Gabb. Proc. Cal. Acad. Sci., Vol. 3, 1863–68, pp. 301–306.

On the fresh-water infusorial deposits of the Pacific Coast, and their connection with the volcanic rocks; by J. D. Whitney. Proc. Cal. Acad. Sci., Vol. 3, 1863–68, pp. 319–324.

Notice of new localities of diamonds in California; by B. Silliman. Proc. Cal. Acad. Sci., Vol. 3, 1863–68, pp. 354–357.

Earthquakes on Kern River, in the central portion of the Sierra Nevada; by J. E. Clayton. Proc. Cal. Acad. Sci., Vol. 4, 1868–72, pp. 38–40.

Remarks on the first discoverer of glaciers in the United States; by George Davidson. Proc. Cal. Acad. Sci., Vol. 4, 1868–1872, p. 162.

Remarks on surface geology as affected by upheavals; by George Davidson. Proc. Cal. Acad. Sci., Vol. 4, 1868–72, p. 179.

On the coast surface and scenic geology; by Amos Bowman. Proc. Cal. Acad. Sci., Vol. 4, 1868–72, pp. 244–245, with plates.

On some of the ancient glaciers of the Sierras; by Joseph Le Conte. Proc. Cal. Acad. Sci., Vol. 4, 1868–72, pp. 259–262.

Remarks on recent earthquake waves; by George Davidson. Proc. Cal. Acad. Sci., Vol. 4, 1868–72, p. 268.

Notes on the geology of the coast of Oregon; by W. A. Goodyear. Proc. Cal. Acad. Sci., Vol. 4, 1868–72, pp. 295–298.

Remarks on the auriferous gravel deposits in Placer County; by J. M. Wiley. Proc. Cal. Acad. Sci., Vol. 5, 1873–74, pp. 14–16.

The abrasions of the continental shores of Northwest America, and the supposed ancient sea-levels; by George Davidson. Proc. Cal. Acad. Sci., Vol. 5, 1873–74, pp. 90–96.

On the artesian wells of Los Angeles County; by A. W. Chase. Proc. Cal. Acad. Sci., Vol. 5, 1873–74, pp. 104–107.

On the auriferous gravel deposits of California; by George Davidson. Proc. Cal. Acad. Sci., Vol. 5, 1873–74, pp. 145–146.

Notes on the high Sierra south of Mount Whitney; by W. A. Goodyear. Proc. Cal. Acad. Sci., Vol. 5, 1873–74, pp. 180–183.

On the great lava flood of the Northwest, and on the structure and age of the Cascade Mountains; by Joseph Le Conte. Proc. Cal. Acad. Sci., Vol. 5, 1873–74, pp. 214–220.

On the auriferous sands of Gold Bluff; by Mr. Chase. Proc. Cal. Acad. Sci., Vol. 5, 1873–74, pp. 246–247, with illustrations.

Notes on some Tertiary fossils from the California coast, with a list of the species obtained from a well at San Diego, California, with a description of two new species; by W. H. Dall. Proc. Cal. Acad. Sci., Vol. 5, 1873–74, pp. 296–299.

The new species described are: *Chrysodomus Diegoensis, Waldheimia Kennedyi.*

Remarks on California coal; by Dr. J. G. Cooper. Proc. Cal. Acad. Sci., Vol. 5, 1873–74, pp. 384–386.

California during the Pliocene epoch; by Dr. J. G. Cooper. Proc. Cal. Acad. Sci., Vol. 5, 1873–74, pp. 389–392.

California in the Miocene epoch; by Dr. J. G. Cooper. Proc. Cal. Acad. Sci., Vol. 5, 1873–74, pp. 401–404.

The Eocene epoch in California: Are there really no Eocene strata? by Dr. J. G. Cooper. Proc. Cal. Acad. Sci., Vol. 5, 1873–74, pp. 419–421.

Note on the Tertiary formation of California; by Dr. J. G. Cooper. Proc. Cal. Acad. Sci., Vol. 5, 1873–74, p. 422.

Cinder cone age of eruption; by H. A. Harkness. Proc. Cal. Acad. Sci., Vol. 5, 1874, p. 408.

On some of the ancient glaciers of the Sierra; by Joseph Le Conte. Proc. Cal. Acad. Sci., Vol. 6, 1875, pp. 38–48, with plate.

The glacial period, its origin and development; by J. E. Clayton. Proc. Cal. Acad. Sci., Vol. 6, 1875, pp. 123–131.

On the result of the glacial action at the head of Johnson's Pass in the Sierras; by James Blake. Proc. Cal. Acad. Sci., Vol. 6, 1875, pp. 170–175.

There were no geological reports in Vol. 7 of the Proceedings of the California Academy of Sciences, published in 1876.

West Coast Pulmonata: fossil and living; by Dr. J. G. Cooper. Proc. Cal. Acad. Sci., 2d ser., Vol. 1, 1888, pp. 11–24. (Continued from Bulletin No. 8, p. 514.)

Notes on the geology of Baja California, Mexico; by W. Lindgren, U. S. Geological Survey. Proc. Cal. Acad. Sci., 2d ser., Vol. 1, 1888, pp. 173–196, with 5 plates.

Description of Pleistocene, Tertiary, Cretaceous, Eruptive, basal granites, and structural features. The author gives a geological profile from San Diego to the Colorado Desert, pl. III.

There were no geological reports in Vol. 2, second series, of the Proceedings of the California Academy of Sciences, published in 1889.

An illustration of the flexure of rock; by George H. Ashley. Proc. Cal. Acad. Sci., 2d ser., Vol. 3, 1890–92, pp. 319–324.

Geological surveys in the State of California; by Anthony W. Vogdes. Proc. Cal. Acad. Sci., 2d ser., Vol. 3, 1890–92, pp. 325–337.

On the discovery of *Proetus ellipticus*, Meek, in the Carboniferous limestone of Shasta County; by A. W. Vogdes. Proc. Cal. Acad. Sci., 2d ser., Vol. 3, 1890–92, p. 376.

On some Pliocene fresh-water fossils of California; by Dr. J. G. Cooper. Proc. Cal. Acad. Sci., 2d ser., Vol. 4, 1894, pp. 166–172, Pl. XIV.

Margaritana subangulata, n.sp.

The Neocene stratigraphy of the Santa Cruz Mountains of California; by George H. Ashley. Proc. Cal. Acad. Sci., 2d ser., Vol. 5, 1895, pp. 273–365, Pls. XXII–XXV.

On fossil and sub-fossil land shells of the United States, with notes on living species; by Dr. J. G. Cooper. Bull. Cal. Acad. Sci., No. 4, 1886, p. 235; No. 7, 1887, p. 355; No. 8, 1887, p. 497.

The Washoe rocks; by George F. Becker. Bull. Cal. Acad. Sci., No. 6, 1887, pp. 93–120.

See also American Naturalist, Vol. 22, 1888, pp. 639–640.

FOREIGN SOCIETIES.

Origin of continents; by W. O. Crosby. Geol. Mag., Vol. 10, June, 1883, pp. 241-252.

Lower Californian eruptive rocks; by E. Ritter. Arch. des Sci., Vol. 33, 1895, p. 330.

Die Californischen Bacillarien-Gebirge; by J. D. Whitney. Monatsber. K. preuss. Akad. Wiss., Berlin, 1872, pp. 124–139.

Zwei profile durch die Sierra Nevada; von E. Reger. Neues jahrbuch IV, Beilage Band 1886, pp. 291–326, plates XVII, with 24 illustrations.

Ueber die wachsende kenntniss des unsichtbaren Lebens als felsbildende Bacillarien in Californien; von Ehrenberg. Berlin Akad. Abhandl., 1870, pp. 126–132; Berlin Monatsber. Akad., 1870, pp. 259–264.

On the gold regions of California; by J. S. Wilson. Jour. Geol. Soc. of London, Vol. 10, 1854, pp. 308–321.

The author gives a geological sketch-map of part of Upper California, comprising the southern mines; section across Upper California from the Pacific to the Sierra Nevada, length 70 miles; Fig. 3, section of auriferous detritus at Sullivan's Gulch; Fig. 4, section of quartz vein in Carson's Hill; Fig. 5, section at Murphy's Deep Diggings.

A contribution to the history of mineral veins; by J. Arthur Phillips. Jour. Geol. Soc. of London, Vol. 35, 1879, pp. 390–396.

On the hot springs of California.

Geologie—Observations sur les gesements aurifères de la Californie; par M. L. Simonin. Comptes Rendus de l'Académie des Sciences, 20 Février, 1860. t. 50, p. 389. Paris.

Sur l'action des anciens glaciers dans la Sierra Nevada de Californie et sur l'origine de la vallée de Yo Semite; par W. P. Blake. Comptes Rendus, Paris, 22 July, 1867. 3 pp.

On the geographical distribution and physical characteristics of the coal fields of the North Pacific Coast; by Robert Brown. Trans. Edinburgh Geol. Soc., 1868–69. 23 pp.

Contains Tertiary coals of the North Pacific: 1. Monte Diablo, California; 2. Coos Bay, Oregon; with analysis of native and imported coals.

Note sur le géologie de la Californie; par Jules Marcou. Bull. Soc. Geol. of France, 1883, pp. 407–435; with geological map of California.

Catalogue of recorded earthquakes from 1606 B. C. to A. D. 1850; by Robert Mallet. Report British Assoc. Adv. Sci., 1854.

Report on the present state of our knowledge with regard to the mollusca of the west coast of North America; by Philip P. Carpenter. Report British Assoc. Adv. of Science, 1856, pp. 159–368.

Supplementary report on the present state of our knowledge with regard to the mollusca of the west coast of North America; by Philip P. Carpenter. Report British Assoc. Adv. of Science, 1864, pp. 517–686.

See also Smithsonian Miscellaneous Collections No. 252. Washington, 1872.

Untersuchungen in Californien; von Jules Marcou. Verhandl. d. K. K. Geol. Reichsanstalt, 1875, pp. 215–216, No. 12.

Sur le gisement de l'or en Californie; par Jules Marcou. Bibliothèque Universalle de Genève, Février, 1854. Genève.

Mikroskopische beobachtungen an Californischen gesteinen; von M. Schuster. Neues Jahrb. 1887, V. Beil. Bd. ss. 451–578, tafel 17–20. (Abstract from American Naturalist, Vol. 22, 1887, p. 452.)

Detailed description of the micro-petrography of eighty rock specimens from the Sierra Nevada, and a discussion of the mineralogic constituents.

Mittheilungen über die Geologie Californiens; von Jules Marcou. Neues Jahrbuch für Mineralogie, Geologie, und Palæontologie, Jahrgang 1883, Bd. II, pp. 52–58.

Beitrag zur Kenntniss der geognostischen Beschaffenheit Californiens; von Dr. G. Grewingk. Verhandlungen der Russisch-Kaiserlichen Mineralogischen-Gesellschaft. zu St. Petersburg. Jahr. 1847, pp. 142–162.

FRANKLIN INSTITUTE JOURNAL AND AMERICAN MECHANICS' MAGAZINE.

Published at Philadelphia.

Experiments on various coals of the Carboniferous and Cretaceous periods, to ascertain their relative potential and economic vaporizations; made by Chief Engineer B. F. Isherwood, U. S. Navy, at the Mare Island Navy Yard, California, in 1871. Journal of Franklin Institute, Vol. 27, 3d ser., No. 6, June, 1872, pp. 392–402.

See Report U. S. Navy Department. House Doc. 42d Cong., 2d session, Ex. Doc. 206, 1872.

HUTCHINGS'S ILLUSTRATED CALIFORNIA MAGAZINE.

A mammoth tusk. Hutchings's Illustrated California Magazine, Vol. 2, 1857–58, pp. 15–16.

HUNT'S MERCHANTS' MAGAZINE.

A history of the discovery of gold in California; by Geo. M. Evans. Hunt's Merchants' Magazine, Vol. 31, p. 385.

JOURNAL OF GEOLOGY.

Published at Chicago, Ill.

Vol. 1, 1893—Vol. 3, 1895.

Revolution in the topography of the Pacific Coast since the Auriferous period; by J. S. Diller. Jour. Geol., Vol. 2, 1894, pp. 32–54.

The Arkansas coal measures in their relation to the Pacific Carboniferous province; by James Perrin Smith. Jour. Geol., Vol. 2, No. 2, February–March, 1894.

The author refers to the Pacific Carboniferous sea under the following headings: Revolution in Devonian time; the Carboniferous sea; Upper Carboniferous in the West; the Pawhuski limestone; interchange of life between East and West; replacement of limestone by the coal-bearing formation in Western Europe; land areas in the West; the Permian Pacific Ocean; Triassic Pacific Ocean.

The Metamorphic Series of Shasta County, California; by James Perrin Smith. Jour. Geol., Vol. 2, No. 6, September–October, 1894.

The author, under "Stratigraphy," gives the following general heading to his article:

Columnar section of the metamorphic series: *Sacramento formation*—Kennett limestones and shales. *McCloud formation*—occurrence and character. *Baird shales*—distribution and fossils; affinities of the fauna. *McCloud limestone*—occurrence and character; fauna of the McCloud limestone. *Pitt formation*—general character of the rocks; the Carboniferous argillites; the Triassic shales and conglomerates. *Cedar formation*—distribution and character; Swearinger slates; Hosselkus limestone; Atractites beds; Spiriferina beds; etc. *Bend formation*—Jura-Trias uncomformity.

Mesozoic changes in the faunal geography of California; by J. P. Smith. Jour. Geol., Vol. 3, No. 4, 1895, pp. 369–384.

The age and succession of the igneous rocks of the Sierra Nevada; by W. H. Turner. Jour. Geol., Vol. 3, No. 4, 1895, pp. 385–414.

The stratigraphy of the California coast ranges; by H. W. Fairbanks. Jour. Geol., Vol. 3, No. 4, 1895, pp. 415–433.

Studies in the Miocene of California; by Geo. H. Ashley. Jour. Geol., Vol. 3, No. 4, 1895, pp. 434–454.

THE MINING MAGAZINE.

Published at New York.

Geology of the Sierra Nevada, or California, range; by Prof. John B. Trask. Mining Mag., Vol. 1, 1853, pp. 6–23.

Mineral districts of Central California; by Prof. John B. Trask. Mining Mag., Vol. 3, 1854, pp. 121–136; continued on pp. 239–250.

Geology of the gold region of California; by Mr. Wilson. Mining Mag., Vol. 3, 1854, pp. 63–64.

Observations on the extent of the gold region of California and Oregon; by William P. Blake. Mining Mag., Vol. 5, 1855, pp. 32–45.

MINING AND SCIENTIFIC PRESS.

Published at San Francisco.

Earthquakes in San Francisco, and specially on their direction; by J. A. Veatch. Mining and Scientific Press, March 31, 1868.

Cinnabar at Point Reyes. Mining and Scientific Press, February 27, 1875.

See also Vol. 27, 1873, p. 166; Vol. 29, Aug. 15, 1874; Vol. 31, 1875, p. 118, for articles and references to the Cinnabar of California.

NATURE.

Prairie mounds of California and Oregon; by Joseph Le Conte. Nature, Vol. 15, 1877, p. 530.

NEW YORK ACADEMY OF SCIENCES.

Silicified wood from California; by James J. Friedrich. Trans. New York Acad. Sci., Vol. 8, 1889, pp. 29–30.

Includes reference to the relations and age of the associated deposits in Lake and Napa Counties.

OVERLAND MONTHLY.

Published at San Francisco, Cal.

On actual glaciers in California; by John Muir. Overland Monthly, December, 1872.

On the earthquake of March 26, 1872; by J. D. Whitney. Overland Monthly, Vol. 9, 1872.

On mountain sculpture in the Sierra Nevada, and the method of glacial erosion; by E. S. Carr. Overland Monthly, May, 1874.

PHARMACEUTICAL JOURNAL.

Report on the geology of the Sierra Nevada, or Californian, range; by John B. Trask. Pharmaceutical Journal, Vol. 14, 1855, pp. 20–24.

PHILOSOPHICAL SOCIETY OF WASHINGTON.

Bulletins: 1880–1895.

Notes on the faults of the Great Basin and of the eastern base of the Sierra Nevada; by J. C. Russell. Washington Philos. Soc. Bull., Vol. 9, 1887, pp. 5–6.

See also Neuer Jahrb., Band 2, 1887, pp. 317–318.

Notes on the geology of Northern California; by J. S. Diller. Washington Philos. Soc. Bull., Vol. 9, 1887, pp. 4–5; additional note on p. 8.

See Am. Jour. Sci. and Arts, 3d ser., Vol. 33, 1887, pp. 152–153; Am. Geologist, Vol. 1, 1888, pp. 125–126; and Popular Sci. Monthly, Vol. 32, 1888, p. 419.

This paper is an abstract of Bull. U. S. Geol. Sur., No. 33.

Stages of geologic history of Sierra Nevada; by G. K. Gilbert. Washington Philos. Soc. Bull., Vol. 9, 1887, p. 7.

Remarks following paper, by J. S. Diller, on geology of Northern California.

NEWPORT NATURAL HISTORY SOCIETY.

ketch of the geological development of the Pacific Slope; by Geo. F. Becker. Proceedings Newport Natural History Society, 1886–87, Document 5. Newport, 1887. pp. 1–12.

PHILADELPHIA ACADEMY OF NATURAL SCIENCES.

Journal, 1st series: Vol. 1, 1817—Vol. 8, 1842.
Journal, 2d series: Vol. 1, 1847—Vol. 10, 1895.
Proceedings, 1st series: Vol. 1, 1841—Vol. 8, 1856.
Proceedings, 2d series: Vol. 1, 1857—Vol. 14, 1870.
Proceedings, 3d series: Vol. 1, 1871—Vol. 24, 1894.

escriptions of new marine shells from Upper California, collected by Thomas Nuttall, Esq.; by T. A. Conrad. Journal Phila. Acad. Nat. Sci., 1st ser., Vol. 7, 1837, pp. 227–268, pl. 17–20.

Several of the species appear in the Tertiary formation of California. A list can be found in Dr. Cooper's catalogues.

otes on the Miocene and Post Pliocene deposits of California, with descriptions of two new fossil corals; by T. A. Conrad. Proc. Phila. Acad. Nat. Sci., Vol. 7, 1855, p. 441.

Ostrea Titan; Pandora bilirata; Cardita occidentalis; Diadora crucibuliformis.

These fossils were afterward described and figured in Pacific Railroad Reports, Vol. VI, 1857.

escriptions of three new genera and twenty-three new species of Middle Tertiary fossils from California and one from Texas; by T. A. Conrad. Proc. Phila. Acad. Nat. Sci., Vol. 8, 1856, pp. 312–316.

Schizopyga Californiana; Cryptomya ovalis; Thracia mactropsis; Mya Montereyana; M. subsinuata; Arcopagia medialis; Tapes linteatumo; Arca canalis; A. trileneata; A. congesta; Axinœa Barbarensis; Mulinia densata; Dosinia longula; D. alta; Pecten Pabloensis; Pallium Estrellanum; Janira bella.

These fossils were afterward described and figured in Pacific Railroad Reports, Vol. VI, 1857, pp. 69–73.

Descriptions of new Cretaceous fossils collected by the Northwestern Boundary Commission on Vancouver's and Sucia Islands; by F. B. Meek. Proc. Phila. Acad. Nat. Sci., 2d ser., Vol. 5, 1861, pp. 314–318.

See also Bull. U. S. Geol. Sur. of the Territories, Vol. 2, 1876.

Descriptions of new species of American Tertiary fossils and a new Carboniferous Cephalopod from Texas; by W. M. Gabb. Proc. Phila. Acad. Nat. Sci., 1861, pp. 367–372.

The following California species are described in this paper:
Turbonilla aspera, n.sp., Miocene, from Santa Barbara.
Modelia striata, n.sp., Miocene, from Santa Barbara.
Sphenia bilirata, n.sp., Miocene, from Santa Barbara.
Venus rhysomia, n.sp., Miocene, from Santa Barbara.
Cardita monilicosta, n.sp., Miocene, from Santa Barbara.
Morrissia Horni, n.sp., Miocene, from Santa Barbara.

Indication of an Elotherium in California; by Joseph Leidy. Proc. Phila. Acad. Nat. Sci., 1868, p. 177.

Elotherium superbus, n.sp., from Calaveras County.

On mastodon remains; by Joseph Leidy. Proc. Phila. Acad. Nat. Sci., 1870, pp. 96–97.

On a mastodon discovered in Contra Costa, California.

Vertebrate fossils from auriferous gravels; by Joseph Leidy. Proc. Phila. Acad. Nat. Sci., 1870, p. 125.

On an extinct whale from California; by E. D. Cope. Proc. Phila. Acad. Nat. Sci., 1871, pp. 29–30.

Remarks on extinct mammals from California; by Joseph Leidy. Proc. Phila. Acad. Nat. Sci., 1872, p. 259.

Extract of a letter relating to mammalian fossils in California; by Dr. L. G. Yates. Proc. Phila. Acad. Nat. Sci., 1874, pp. 18–21.

This paper gives a list of localities—fossil elephas, and fossil mastodon.

The blue gravel of California; by E. Goldsmith. Proc. Phila. Acad. Nat. Sci., 1874, pp. 73–74.

Descriptions of new fossil shells from the Tertiary of California; by R. E. C. Stearns. Proc. Phila. Acad. Nat. Sci., 1875, pp. 463–464, pl. 27.

Opalia varicostata, n.sp.; *O. anomala*, n.sp.

Note on a Cerripede of the California Miocene, with remarks on fossil shell; by R. E. C. Stearns. Proc. Phila. Acad. Nat. Sci., 1876, pp. 273–275.

The author refers *Tamiosma gregaria*, Conrad, to the genus *Balanus*.

On the occurrence of Ammonites in deposits of the Tertiary age; by A. Heilprin. Proc. Phila. Acad. Nat. Sci., 1882, p. 94.

On the age of the Tejon rocks of California and the occurrence of Ammonitic remains in Tertiary deposits; by A. Heilprin. Proc. Phila. Acad. Nat. Sci., Vol. 34, 1882, pp. 196–214.

The author remarks (p. 213) that the rocks of the Tejon group (Cretaceous, Div. B, of the California Survey), despite their comprising, in their contained faunas, a limited number of forms from the subjacent (Cretaceous) deposits, and a few undoubted representatives of the *Ammonitidæ*, are of Tertiary (Eocene) age.

The Eocene age of the Tejon rocks is also maintained by Prof. Jules Marcou, who made a personal examination of the region. (Rept. Chief Engineers, 1876, p. 387.)

On supposed Tertiary Ammonites; by J. S. Newberry. Proc. Phila. Acad. Nat. Sci., 1882, pp. 194–195.

Age of Tejon rocks of California and the occurrence of Ammonitic remains in Tertiary deposits; by A. Heilprin. Proc. Phila. Acad. Sci., 1890, pp. 445–489.

Extinct mammalian fauna of Dakota and Nebraska, including an account of some allied forms from other localities; by J. Leidy. Jour. Phila. Acad. Nat. Sci., Vol. 7, 1869.

PUBLICATIONS OF U. S. NATIONAL MUSEUM.

Post Pliocene fossils in the Coast Range of California; by W. H. Dall. Proc. U. S. Natl. Mus., Vol. 1, 1878, p. 3.

Specimens of *Donax Californicus*, *Chione succincta*, *Olivella biplicata*, and *Certhidea sacrata* in a semi-fossilized condition from San Luis Rey, Cal.

Fossil mollusca from later Tertiary of California; by W. H. Dall. Proc. U. S. Natl. Mus., Vol. 1, 1878, pp. 10–16.

The author gives a table of one hundred and seven species, ten of which are extinct and ninety-seven still found recent, with a description of the following new species: *Arinea profunda, Pecten expansus, P. Stearnsi, P. Hemphilli, Anomia lunatula, Scalaria Hemphilli.*

Distribution of Californian Tertiary fossils; by W. H. Dall. Proc. U. S. Natl. Mus., Vol. 1, 1878, pp. 26–30.

The author notes those of the strata of the San Diego Peninsula and those of the mainland, near the town of San Diego, etc.

Jurassic or Cretaceous beds appear to exist at Todos Santos Bay, Lower California, not far from San Diego.

Note on the occurrence of *Productus giganteus* in California; by C. A. White. Proc. U. S. Natl. Mus., Vol. 3, 1880, pp. 46–47, pl. 1.

From the Carboniferous of McCloud River, Shasta County, California.

Directions for collecting and preparing fossils; by Charles Schuchert. Bull. U. S. Natl. Mus., No. 39. Washington, 1895.

Contains California localities of fossils.

SANTA BARBARA SOCIETY OF NATURAL HISTORY.

Infusorial earth at Santa Barbara, California; by W. W. Finch. Santa Barbara Soc. Nat. Hist., Bull. No. 1, 1887, pp. 8–11.

ST. LOUIS ACADEMY OF SCIENCES.

Descriptions of new fossils from the Tertiary formation of Oregon and Washington Territories, and the Cretaceous of Vancouver's Island, collected by Dr. John Evans, U. S. Geologist, under instructions from the Department of the

Interior; by B. F. Shumard. Trans. St. Louis Acad. Sci., Vol. 1, 1858, pp. 120–125.

These fossils were obtained from Port Orford, Willamette Valley, Coos Bay, and Vancouver's Island. The following are described but not figured: *Lucina fibrosa*, n.sp.; *Corbula Evansana*, n.sp.; *Leda Willamettensis*, n.sp.; *L. Oregona*, n.sp.; *Pecten Coosensis*, n.sp.; *Venus securis*, n.sp. From the Cretaceous of Vancouver's Island: *Inoceramus Vancouverensis*, n.sp.; *Pinna calamitoides*, n.sp.; and *Pyrula glabra*, n.sp.

SCIENCE.

Sierra structure; by G. K. Gilbert. Science, March 23, 1883, p. 195.

Coal in the Chico group of California; by J. S. Diller. Science, Vol. 5, 1885, p. 43.

This announcement shows that the Chico group, like its equivalent, the Nanaimo group, is a coal-bearing bed.

The author states that a number of fossils were collected from the coal-bearing strata in Northern California, eight miles northeast of Yreka, on the road to Linkville, Oregon. He does not give a list, which is given in Dr. White's report on the Chico group.

The latest volcanic eruption in the United States; by C. E. Dutton. Science, Vol. 6, 1885, p. 46.

Agriculture and late Quaternary geology; by E. W. Hilgard. Science, Vol. 11, 1888, pp. 241–242.

Descriptions of evidence of an ancient drainage system in the Upper San Joaquin Valley, California.

North American Mesozoic; by Charles A. White. Science, Vol. 14, 1889, pp. 160–166.

Correlations of Tejon deposits with Atlantic stages of the Gulf slope; by G. D. Harris. Science, Vol. 22, 1893, p. 97.

Petroleum in Southern California; by S. F. Peckham. Science, Vol. 23, 1894, pp. 74–78.

SCHOOL OF MINES QUARTERLY.

The genesis and distribution of gold; by J. S. Newberry. School of Mines Quarterly, Nov., 1881.

Notes on the dry lakes of Southern Nevada and California, with relation to the Lœss; by Walter P. Jenney. School of Mines Quarterly, Vol. 10, 1889, pp. 316–318.

Description of the lakes, their deposits and history.

WEST AMERICAN SCIENTIST.

Published at San Diego, Cal.

(C. R. Orcutt, Editor.)

New Cretaceous fossils. West American Scientist, Vol. 3, pp. 28–31.

Trochus (Oxystele) euryostomus, White; *Cerithium Pillingsi*, White; *C. totium sanctorum*, White; *Solarium Wallalensis*, White; *Nerita Californiensis*, White.

All these fossils were described in U. S. Geol. Sur. Bull. No. 22, 1885, except *Nerita Californiensis*.

Minerals and mines of San Diego; by C. R. Orcutt. West American Scientist, Vol. 3, p. 69.

Gypsum on the coast of Lower California; by M. Lopateck West American Scientist, Vol. 3, p. 117.

Fossil botany; by Dr. L. G. Yates. West American Scientist Vol. 3, p. 180.

Fossil botany, No. 2; by Dr. L. G. Yates. West American Scientist, Vol. 3, p. 201.

Fossil botany, No. 3; by Dr. L. G. Yates. West American Scientist, Vol. 3, p. 213.

Fossil botany, No. 4; by Dr. L. G. Yates. West American Scientist, Vol. 4, p. 20.

Fossil botany, No. 5; by Dr. L. G. Yates. West American Scientist, Vol. 5, p. 39.

Fossil ferns; by O. D. Walbridge. West American Scientist, Vol. 3, p. 217.

A study of river geology; by W. R. Lighton. West American Scientist, Vol. 4, p. 24.

The gold fields of Lower California; by C. R. Orcutt. West American Scientist, Vol. 6, p. 4.

Some notes on Tertiary fossils of California; by C. R. Orcutt. West American Scientist, Vol. 6, p. 70.

Gives list of fossils at Pacific Beach, San Diego.

Some notes on Tertiary fossils of California; by C. R. Orcutt. West American Scientist, Vol. 6, p. 84.

List of fossils in a San Diego well.

The California geysers; by Joseph Keep. West American Scientist, Vol. 6, p. 99.

TRANSACTIONS ALBANY INSTITUTE.

Description of new organic remains from the Cretaceous rocks of Vancouver's Island; by F. B. Meek. Trans. Albany Inst., Vol. 4, 1857, pp. 37–49. See also Bull. U. S. Geol. Sur., Vol. 2, No. 4, 1876.

Gabb, in the Palæontology of California, refers to the following species in this article: *Pholadomya subelongata*, Meek; *Ammonites* (*Scaphites?*) *ramosus*, Meek; *A. Newberryanus*, Meek; *Baculites ovatus*, Say?, for which Meek suggests the name of *B. occidentalis*.

TRANSACTIONS AMERICAN INSTITUTE OF MINING ENGINEERS.

Published at New York City.

The production of gold and silver in the United States; by R. W. Raymond. Trans. Amer. Inst. Mining Engineers, Vol. 3, p. 202; see also Vol. 5, p. 175.

Mercury associated with bitumen; by T. Egleston. Trans. Amer. Inst. Mining Engineers, Vol. 3, p. 273.

Geology of American Valley. Trans. Am. Inst. Mining Engineers, Vol. 13, p. 217.

The silver mines of Calico, California; by W. Lindgren. Trans. Amer. Inst. Mining Engineers, Vol. 15, p. 717–734.

Description and sections of the region, and discussion of the lithological, stratigraphic, and structural features of the Tertiary sandstones, tuff deposits, liparite, and andesite, and their relations to the ore deposits.

Hydraulic mining in California; by A. J. Bowie, Jr. Trans. Amer. Inst. Mining Engineers, Vol. 6, 1879, p. 27.

Contains map of river tunnel on Mariposa Estate.

Mining developments on the northwestern Pacific Coast, and their wider bearing; by Amos Bowman. Trans. Amer. Inst. Mining Engineers, Vol. 15, 1887, pp. 707–717.

ZOE.

Published at San Francisco, Cal.

On the discovery of *Proetus ellipticus*, Meek, in Shasta County, California, which is referred to the Waverly group; by A. W. Vogdes. Zoe, Proceedings of Societies, Vol. 3, 1892, p. 274.

Notes on the geology of the Farallones; by J. W. Blankinship. Zoe, Vol. 3, 1892, pp. 145–146.

PART IV.

Publications of State Geological Surveys other than that of California.

MISSOURI GEOLOGICAL SURVEY.

(Volume VI.)

Lead and zinc deposits; by Arthur Winslow, assisted by James D. Robertson. Jefferson City, 1894. 2 vols.

On page 187 the author states that although California is not classed as a lead- and zinc-producing State, it contains extensive deposits of lead-producing ores. These occur principally in Inyo and San Bernardino Counties, in the southwestern portion of the State. He gives the localities of the lead deposits of San Bernardino County, near Kingston Mountain, in dolomitic limestone; near Denby, in the Old Woman Mountains. He mentions a large and extensive ledge of carbonate and galena in granite and slate formations. Other localities are mentioned, both in Inyo and San Bernardino Counties, on the authority of the Ninth Annual Report of the State Mineralogist; 10th and 11th Census Reports.

PART V.

Miscellaneous Publications.

(*Alphabetical List.*)

AARON, C. H. Practical treatise on testing and working silver ore. San Francisco, 1876. 114 pp.

—— Assaying. In three parts; in two volumes. San Francisco, 1885.

—— Leaching gold and silver ores. San Francisco, 1880.

AIMARD, GUSTAVE. The goldseekers. Philadelphia, 1863. 12mo.

ALLEN, W. W., *and* AVERY, R. B. California gold book. First nugget; its discovery and discoverers, and some of the results proceeding therefrom. San Francisco and Chicago, 1893. 439 pp.

There are some geological notes given in Chapter XII, under the heading of Gold.

ALLSOPP, ROBERT. California and its gold mines. Being a series of recent communications from the mining district upon the present condition and future prospects of quartz mining. London, 1853. 149 pp.

This work contains a letter on the advantages of California, and also an article entitled, Why quartz companies are failures.

ANDERSON, ALEXANDER D. The silver and gold of the Southwest. St. Louis, 1877.

ANDERSON, C. L. The natural history of Santa Cruz County, comprised in chapters on Geology, Marine and Land Botany, Fishes and Birds, for the use of students of all ages, in or out of schools, and the public generally. Oakland, 1894. 67 pp.

ANDERSON, WINSLOW. Mineral springs and health resorts of California, with a complete chemical analysis of every important mineral water in the world. San Francisco, 1890. 384 pp. illustrated.

This book contains brief geological descriptions on the formation of mineral springs, causes of subterranean heat, with notes on the mineral springs of the Coast Range, etc.

ANSTED, DAVID THOMAS. The goldseeker's manual. London, 1849. 96 pp.

ASHBURNER, WILLIAM. Report of California Water Company. 1880. San Francisco, 1880.

Contains report upon the property of the California Water Company, by W. Ashburner; with report on gold mines, by E. P. Hutchins, and report of Amos Bowman.

—— Report of the Sulphur Bank Quicksilver Mining Company, Lake County, California. 1876.

Contains reports by William Ashburner, James D. Hague, Thomas Price, and M. C. Vincent. A general description of Clear Lake region is given on page 5.

—— Report upon Approach Gold Quartz mine. San Francisco, 1866.

ATTWOOD, MELVILLE. On the milling of gold quartz—amalgamation. In Mining and Scientific Press, August 20, 1881. tract of 5 pages.

—— Paper on the microscopical examination of rocks. San Francisco, 1888.

BARRY, JOHN D. Report on the proposed Eocene tunnel at Big Bend, on the North Fork of the Feather River, Butte County, California.

Contains map and section of rocks.

BECKER, GEORGE F. The structure of a portion of the Sierra Nevada in California. 1891. tract.

BEECHEY, CAPT. F. W. Narrative of a voyage to the Pacific and Behring's Strait, to coöperate with the Polar expedition

performed in his Majesty's ship Blossom, under the command of Capt. F. W. Beechey. London, 1831. 2 vols.

In the volume on the zoölogy of Captain Beechey's voyage (London, 1839, 4to), by Prof. Buckland, there are several references to the geology of the vicinity of San Francisco, prepared from the notes and collections of Lieutenant Belcher.

A map of the headland, embracing San Francisco Bay, accompanies this report. This is colored around the shores so as to indicate the several formations; serpentine, sandstone, and jasper rock are represented. Lieutenant Belcher collected specimens of serpentine on the west side of Angel Island. The occurrence of jasper rock is also noted.

The author, on page 174, gives the following account of the geology of California, which was the first ever published; it is given in full, on account of its value:

GEOLOGY, BAY OF SAN FRANCISCO.

"The specimens collected in and near the Bay of San Francisco consist of many varieties of common serpentine, bronzite, and asbestos; clay-slate and mica slate, chlorite slate, horn-stone, brown, green, and red jasper, and rolled blocks of glassy actynolite; grey sandstone, and imperfect wood-coal. The country near the port of San Francisco is composed chiefly of sandstone, jasper, and serpentine. Wood-coal is found in slight seams on the north side of the entrance of the bay, and native salt near Santa Clara. Many of the summits of the hills are composed of jasper, forming enlongated ridges, of which the general direction is north and south. This jasper is succeeded by sandstone, of a loose texture, not effervescing with acids, and disposed in every angle of stratification, occasionally it is hard and of a blue cast; it is frequently interrupted by abrupt masses of laminated jasper in wavy stratification. The appearance of the jasper, at its contact with the sandstone, is often very remarkable. The jasper appears not to have acted on or displaced the sandstone; its exterior, for eighteen inches or two feet, is usually rugged, and mixed with carbonate of lime, quartz, and indurated clay; its interior, however, presents a very beautiful wavy disposition of the component laminæ, a remarkable example of which occurs at the Needle Rock, nearly opposite the fort. A view of it is engraved at Pl. III, Geology. It resembles an immense mass of sheets of paper, or bands of list, crumpled and contorted by lateral pressure. This contortion only occurs in the red jasper, the yellow being seldom (if at all) stratified, but generally separated by cracks into rhomboidal pieces. A mass of at least one hundred feet in thickness is beautifully stratified in short, wavy lines, opposite the fort near Punta Diavolo, and rests on sandstone.

"Between Punta Boneta and Punta Diavolo the sandstone is of a bluish-grey colour, containing particles of coal.

"The Island of Los Angelos is of very confused formation. Its eastern side is sandstone, with occasional jasper rocks; its western side exhibits sandstone, conglomerate, clay-slate, and serpentine; its south side, bluish earth, (apparently decomposed serpentine), and jasper beds containing red siliceous nodules, and much iron pyrites.

The superstratum of this island is almost entirely composed of the débris of sandstone and jasper rocks, a little slate and bluish earth, and betrays appearances of violence. It is about 900 feet above the level of the sea.—B.

"The cliffs of the main land, opposite the northwest shore of the Island of Los Angelos afford masses of actynolite and beds of mica slate and talc slate.

"The Island of Molate, about four miles north of Los Angelos, appears at a distance to be of a red colour, and contains much red jasper, and in a small portion of the cliff black ferruginous slate.—C.

"In the Island of Yerba Buena, the perpendicular cliffs west of the bay are formed of clay-slate at their base, whilst the superincumbent rock is sandstone, for the most part in angular masses, and without distinct stratification. The clay-slate is much contorted, arched, and wavy, assuming an east and west direction, and dipping chiefly to the south at a considerable angle. The sandstone shows itself in the point that forms the eastern part of the bay.

"The rounded hills of the peninsula on which the Presidio of San Francisco is placed, are variously formed of sandstone, loose sand, serpentine, flinty slate, and jasper. The westernmost hill, which rises from the sea between the fort and the Punta di los Lobos, is serpentine. The north declivity, on which the quadrangle of the Presidio is built, is sandstone. To the eastward of this the serpentine again forms a hill of equal if not greater height. The hill to the westward of the Mission is serpentine. That which rises to the south of it exposes a bare and scarped brow of flinty slate and jasper. Rocks of a similar nature protrude through the surface of the soil of the hills which separate San Francisco from the extensive valley of Santa Clara (Las Salinas), about six leagues to the southward. These hills are called Sierras di los Samburnos, and terminate on the north in a rocky prominence, in the harbour east of the inlet of the Mission.

"The range of mountains, Las Sierras del Sur, which bound the above valley to the south, expose flinty slate approaching to jasper, a little northwest of Las Pulgas, and about eighteen miles east-southeast of the Mission of San Francisco. Between the Missions of Santa Clara and Santa Cruz, these mountains form four parallel ranges, the two middle ones highest (about 1,500 feet), with steep declivities; the first two valleys are narrow; the third is more extensive, leading to the fourth range, which is considerably lower than the others. The first two ridges are composed of serpentine and a jaspery rock, the third principally of sandstone and occasionally jasper, and the fourth, that nearest Santa Cruz, entirely of sandstone, the upper part being mostly decomposed into loose sand. Petrified bones of a cylindrical form were found in this cliff of sand or loose sandstone in 1827.

"Where this range approaches the road from Santa Clara to San Juan, nearly half-way, the northern declivity is covered with fragments of serpentine, and a little farther on is sandstone and flinty slate.

"In the neighbourhood of the Mission of San Juan is a sandstone conglomerate, and on the road crossing from San Juan to the plain of Monterey, is sandstone. From the interior of the range between San Juan and Monterey, the inhabitants of Las Animas had brought compact basalt, containing particles of magnetic iron ore, which

encouraged the delusive hope of rich mines. A few miles down the river Paxaros, from where the road to San Juan crosses it, there are thermal springs, and sulphur in their neighbourhood. On the Santa Cruz side, near the Mission, there is said to be coal, but it has never been mined. Along the east shore of the Bay of San Francisco, for thirty-five miles east-southeast, from beyond the Island of Molate, towards San Josef and Santa Clara, the harbour is bounded generally by low alluvial soil, and only in a few places do low and rocky cliffs protrude. Near the Mission of San Josef there are some hot springs in the plain, surrounded by a verdant covering. Earthquakes are rather common, and one in 1806 so shook the building of the Mission of Santa Clara, that a new one was obliged to be erected. A few years ago, a boat belonging to a whale ship, when lying in several feet water, was suddenly thrown on the beach and left dry, and a vessel in the Bay of Monterey was suddenly and severely tossed about by the sea, and the shock was felt on the shore at the same time. At ten o'clock on the 26th December, 1827, a slight shock was felt at San Josef. The shocks are said to come along the coast from the northward, and when they are also felt at Monterey it is some minutes later.

"One was perceived at the Presidio of San Francisco in the month of April, 1827. It continued a short time, but the shaking was so slight that it injured nothing.—C."

BELL, WILLIAM A. New tracks in North America. London, 1870. 564 pp.

Gives history of mining under the Spaniards, mines along the Colorado, etc. pp. 426 *et seq.*

BERRY, GEORGE. The gold of California. London, 1849.

BLAKE, W. P. Notice of remarkable strata containing the remains of Infusoria and Polythalamia in the Tertiary formation of Monterey, California. Philadelphia, 1855. tract.

—— Observations on the characters and probable geological age of the sandstone formation of San Francisco. Washington, 1855. tract.

—— Observations on the extent of the gold region of California and Oregon, etc. New Haven, 1855. tract. (In Am. Jour. Sci., Vol. 20, pp. 72–85.)

—— Remarks upon the geology of California. Washington, 1855. tract.

—— Sur l'action des anciens glaciers dans la Siérra Nevada de California, et sur l'orgine de la Vallée de Yo-Semite. Paris, 1867. tract. 4to.

BLAKE, W. P. Note upon the occurrence of fossil remains of the tapir in California. New Haven, 1868. tract.

—— Geological reconnoissance in California. New York, 1858.

—— The production of precious metals. New York, 1869.

BORTHWICK, J. D. Three years in California. Edinburgh, 1857. 384 pp. illustrated.

Chapter XIX treats of the northern and southern mines.

BOUND HOME, or the Gold-Hunter's Manual. New York, 1852.

BOUCHACOURT, C. Notice industrielle sur la Californie. Lyons, 1849.

BOURNE, B. F. Captive in Patagonia. Boston, 1853.

Contains much about California.

BOWIE, AUG. J. Hydraulic mining in California. San Francisco, 1878.

—— Practical treatise on hydraulic mining in California. New York, 1885. 313 pp. 72 plates and illustrations.

—— *Same.* New York, 1887. 313 pp. maps, plates, and sections.

—— Mining débris in California rivers. 80 pp. 5 plates.

BOWMAN, AMOS. Coast surface and scenic geology of California, 1873. 8 plates.

—— Report on the properties and domain of the California Water Company, situated on Georgetown Divide; embracing the mining, water, and landed resources of the country between the South and Middle Forks of the American River, in El Dorado County, California. San Francisco, 1874. 225 pp. maps, plates, and illustrations.

The report contains a section on vein systems, their origin and relations.

BROOKS, J. T. Four months among the gold-finders in Alta California. London, 1849. 207 pp.

BROWNE, J. ROSS. The Coast Ranges; a chronicle of events in California. A series of articles in Harper's Magazine for 1861–62.

June number, 1861, Vol. XXIII, No. 1, pp. 1–14.
August number, 1861, Vol. XXIII, No. 2, pp. 306–316.
September number, 1861, Vol. XXIII, No. 3, pp. 593–606.
December number, 1861, Vol. XXIV, No. 4, pp. 1–16.
February number, 1862, Vol. XXIV, No. 5, pp. 289–301.

BRYANT, EDWIN. What I saw in California. Being a journal of a tour by the emigrant route and South Pass of the Rocky Mountains across the continent of North America, the Great Basin, and through California, in the years 1846 and 1847. London, 1849. 412 pp.

The appendix gives an account of the discovery of gold mines in California.

BUFFUM, E. GOULD. Six months in the gold diggings, and scenes in Upper and Lower California, from 1847 to 1850. Philadelphia, 1850. 172 pp.

Chapter VIII treats of the extent and richness of the California gold fields.

BURNETT, PETER H. Recollections and opinions of an old pioneer. New York, 1880. 448 pp.

Chapter VI treats of the gold discovery in California.

BUTLER, A. W. Resources of Monterey County. San Francisco, 1875.

CALIFORNIA GOLD REGIONS, with a full account of the mineral resources, etc. New York, 1849. 48 pp.

CALIFORNIA; its gold and its inhabitants. London, 1856. 2 vols.

—— Description of the recently discovered petroleum region in California. New York, 1865. tract.

—— Its past history; its present position; its future prospects, etc., with an appendix containing the official reports made to the Government of the United States. London, 1850. 270 pp.

LIFORNIA, Life in; by an American. New York, 1846. 341 pp.

On page 90 the author speaks of visiting a spot on the Alisal, near Monterey, from which considerable quantities of silver ore had been obtained. It was the first mine discovered in California, from this author's account.

— California as it is. Being a concise description of the State by counties, with memoranda of the progress of each agricultural, horticultural, mining, and other industries up to the year 1887–88, etc. San Francisco, 1888. 257 pp. map.

There are five editions of this work. The first one was published by the Daily and Weekly Call in 1882.

RPENTER, PHILIP P. Lectures on the shells of the Gulf of California. Washington. 25 pp. 6 illustrations.

This aticle appeared in the Annual Report of Smithsonian Institution, 1859.

RSON, J. H. Early recollections of the mines. Stockton, 1852.

STANARES, MANUEL. Letters from California addressed to the President of the Republic of Mexico. City of Mexico, 1845.

Manuel Castanares was a Representative in the National Congress, from the Department of California, in 1845. In his first letter, under date of March 2, 1844, the author states that gold placers were discovered in California last year, extending some thirty leagues. In his second letter, under date of September 1, 1844, the writer states: "The mining interest in California is of great importance, and I have the satisfaction of assuring your Excellency that it forms one of the most valuable resources of this Department. Besides the silver mines which are found, there are various other mines which have actually yielded metals; the gold placer especially is worthy of great attention, which extends nearly thirty leagues, was discovered lately, together with mines of mineral coal."

AUDET, F. G. Gold. New Westminster, 1871.

IGNET, M. Rapport sur les mines de New Almaden. Paris, 1866.

LTON, WALTER. The Land of Gold, or three years in California: a diary from 1846 to 1849. New York, 1860. 456 pp.

Chapter XXVII treats of the gold region, its locality, nature, and extent. Chapter XXX treats of the gold-bearing quartz, their locality, richness, and extent.

COOPER, A. S. The genesis of petroleum and asphalt in California. Scientific American Supplement, September 2, 1893, and December 30, 1893.

Red shales, as connected with the genesis of bitumen in California. The most important asphalt deposits in California are in Tertiary rocks. In Kern County they occur in veins and superficial beds; in Santa Cruz County, bituminous beds are mined; in San Luis Obispo County, in strata and as superficial deposits from springs; in Santa Barbara County, mixed with sand and other substances found in veins and beds, and in sandstone and shale; in Ventura County, in irregular veins and impregnating sandstone.

COOPER, DR. J. G. Resources of San Luis Obispo County. San Francisco, 1875.

CORY, THOMAS G. Gold from California. Lecture, March 25, 1856.

COULTER, THOMAS. Notes on Upper California. In Geog. Soc. Journal, Vol. 5, 1835, pp. 59–69.

CRONISE, TITUS F. The natural wealth of California. San Francisco, 1868. 696 pp.

Comprising early history; geography, topography, and scenery; climate; agriculture and commercial products; geology, zoölogy, and botany; mineralogy, mines, and mining processes; manufactures; steamship lines, railroads, and commerce; immigration, population, and society; educational institutions and literature; together with a detailed description of each county, its topography, scenery, cities and towns, agricultural advantages, mineral resources, and varied productions.

Chapter VI treats of geology of the State; principally taken from Professor Whitney's reports, Pacific Railroad Reports, and Blake's Geological Reconnaissance in California, etc.

DANA, JAMES D. Manual of Geology, treating of the principles of the science, with special reference to American geological history. 2d edition. New York, 1874. 828 pp. (Third edition, New York, 1895.)

This work contains special articles on California artesian wells, p. 654; also, notes on the Carboniferous, Cretaceous, Jurassic, Quaternary, sub-Carboniferous, Tertiary, and Triassic formations; with references to geysers, hot springs, human relics, and terraces in California.

DAVIES, WILLIAM O. Report of the Pacific Coal Company. New York, 1865. 10 pp.

Contains report of borings by W. O. Davies; coal fields on the Marsh ranch, in Contra Costa County, with section showing the dip of veins.

DAVISON, SIMPSON. The discovery and geognosy of the gold deposits in Australia, with comparisons and accounts of the gold regions of California, etc. London, 1860. 36 pp.

Devoted to personal experience in the gold mines of California.

DELANO, A. Life on the plains and among the diggings. Being scenes and adventures of an overland journey to California, with particular incidents of the route, etc. Auburn and Buffalo, 1854. 384 pp.

Chapter XXVII treats of the resources of California, mineral wealth, etc.

DELESSERT, B. Les mines d'or de la Californie. 17 pp. tract. (Rev. d. Deux Mondes, Vol. 5, 1849, p. 468.)

DELMAR, ALEXANDER. A history of the precious metals. London, 1880.

DENIS, FERD. Les Californiens. Paris, 1849. pamphlet. 45 pp.

This is an historical account of the settlement of California.

DUNBAR, E. E. Romance of the age, or discovery of gold in California. New York, 1867. 134 pp.

The author gives an account of the discovery of gold in California, with a brief history of previous accounts of gold mentioned by writers before 1848.

ELMORE, M. G. Esmeralda mining map. New map of the Esmeralda mining district to December, 1862. San Francisco, 1862.

These mines are south of Washoe, on the eastern slope of the Sierra Nevada, and partly in California.

EVANS, ALBERT S. A la California. Sketches of life in the Gold State. San Francisco, 1873.

The author gives passing references to mining, with illustrations.

FARNHAN, T. J. Life and adventures and travels in California. New York, 1852. 514 pp.

—— *Same.* New York, 1857. 468 pp. illustrated.

FEDIX, ——. Les côtes des Pacifique. Paris, 1846. 258 pp. maps.

FERRY, HYPOLITE. Description de la nouvelle Californie, géographique, politique, et morale. Paris, 1850. 386 pp.

Chapter III treats of the climate and mountain chains.
Chapter IV treats of the auriferous regions of California.

FEUCHTWANGER, DR. LOUIS. Valuable mining tables for ascertaining the weight of a cubic foot of any ore, metal., etc. (In California Farmer, Vol. 29, No. 14, April 9, 1868. Also published as broadside.)

FORTUNE, H. W. Report of the property of Trinidad Copper Mining Company, Lower California. San Francisco, 1879. 11 pp. sections.

FOSTER, G. G. The gold regions of California. Being a succinct description of the geography, history, topography, and general features of California: including a carefully prepared account of the gold regions of that fortunate country, prepared from official documents and other authentic sources. New York, 1848. 80 pp. and map.

FRIGNET, ERNEST. La Californie Histoire—organisation, politique et administrative, Législation, Description, Physique et Géologique, Agriculture, Industrie, Commerce. Paris, 1866. 471 pp.

Livre 3, Chap. I, treats of the geology.

FRÉMONT *and* EMORY. Notes of travel in California, comprising the prominent geographical, agricultural, geological, and mineralogical features of the country; also the route to San Diego, in California, including parts of the Arkansas, Del Norte, and Gila Rivers. Dublin, 1849. 311 pp.

FROST, JOHN. History of the State of California. Auburn, 1850. 508 pp.

Chapter XIII treats of the mineralogical and other characteristics of gold, etc.

GEOLOGY of California, the supply of silver and gold. tract. 19 pp. (N. Amer. Rev., Vol. 75, 1852, p. 277.)

GILPIN, WILLIAM. The central gold region; the grain, pastoral, and gold regions of North America, with some new views of its physical geography; and observations on the Pacific Railroad. Philadelphia, 1860. 194 pp. maps.

GOLD mines and mining in California. A new gold era dawning on the State; progress and improvements made in the business; perfected methods; progress and machinery; vast extent of auriferous territory; rich and varied character of deposit; a country abounding with elements of success; grand field for the profitable investment of the world's surplus capital. San Francisco, 1885.

Under the general heading of Hydraulic Mining, pp. 63–82, the author gives a few geological notes on the Pliocene rivers. On p. 333, a short account of the auriferous deposits peculiar to California. The Gold Bluffs and beaches is given, with a description of those of Humboldt County.

GOODYEAR, W. A. The coal mines of the western coast of the United States. San Francisco, 1877. 153 pp.

The part relating to California was republished, with additional notes and corrections, in the Seventh Annual Report of the State Mineralogist.

GREGORY, J. G. Guide to California and the Isthmus of Panama. New York, 1850.

HANKS, HENRY G. Address of the President of the California State Geological Society. Daily Alta, January 8, 1877.

—— Geological Society. Celebration of the first anniversary of the organization. Daily Alta, December 6, 1877.

These two papers were issued in pamphlet. They contain a list of private owners of mineral collections; also, notes on diatomaceous earth of the Pacific Coast.

—— Catalogue of the minerals, ores, rocks, and fossils of the Pacific Coast exhibition at the Paris Exposition of 1878. pp. i–xxiv and 1–99.

—— Coal and iron interest of the Pacific Coast. San Francisco, 1888. tract.

—— Notes on mica. San Francisco, 1882. tract.

—— The deep placers of California. In Mining and Scientific Press, 1890.

—— Magnesia and its base and compounds, with particular reference to magnesite. San Francisco, 1895. 27 pp.

HART, ALBERT. **Mining statutes of the United States, California, and Nevada. San Francisco, 1877. 183 pp.**

HASTINGS, L. W. **A new description of Oregon and California, containing complete descriptions of those countries, together with the Oregon treaty and correspondence, and a vast amount of information relating to the soil, climate, productions, rivers and lakes, and the various routes over the Rocky Mountains; also an account, by Col. R. B. Mason, of the gold region, and a new route** to California. Cincinnati, 1849. 168 pp.

HELPER, H. R. Land of gold: reality vs. fiction. Baltimore, 1855. 300 pp.

HITTELL, JOHN S. The resources of California, comprising agriculture, mining, geography, climate, commerce, etc., and the past and future development of the State. 5th edition, with an appendix on Oregon, Nevada, and Washington Territory. San Francisco, 1869. 504 pp.

The first edition of this work was published in 1862. Chapter III treats of geology. There is also a chapter on mining.

Edition published in San Francisco, 1863, 1 vol., large 12mo, contains 461 pp.; another edition in 1866, 1 vol., large 12mo.

HOLLAND, CHARLES. Mines and mining. In the Coast Review, 1873, p. 73.

HUSE, CHARLES E. Sketch of the history and resources of Santa Barbara city and county. Santa Barbara, 1876.

HUTCHINGS, J. M. Scenes of wonder and curiosity in California. 1860. 236 pp. 92 illustrations.

—— Another edition. London, 1865. 267 pp. 100 illustrations.

—— Another edition, to which is added a tourist guide to the Yosemite Valley. New York, 1876. 292 pp. 100 illustrations.

HUNTLEY, SIR HENRY. California; its gold and its inhabitants. London, 1856. 2 vols.

JACKSON, ——. Map of the mining districts of California. 1851. Colored map, 18 x 22 inches.

The appendix to this map contains 16 pages.

JACKSON, C. T. The oil interest of southern coast of California. San Francisco Bulletin, July, 1865.

JOHNSON, T. T. Oregon and California, or sights in the gold region and scenes by the way. New York, 1849. 290 pp. (Also published New York, 1850. 324 pp.)

Chapters XXVII and XXVIII treat of the gold regions, volcanic formations of California, etc.

The first edition was published in 1849. A second edition was published in April, 1850, with the addition of eight new chapters, viz., Chapters VI, XXV, XXVI, XXVII, XXVIII, XXIX, XXXI. There were no illustrations in the first edition.

KELLY, WILLIAM. Excursion to California over the prairie, Rocky Mountains, and Great Sierra Nevada, with a stroll through the diggings and ranches of that country. London, 1851. Vol. 1, 342 pp.; Vol. 2, 334 pp.

KING, CLARENCE. Mountaineering in the Sierra Nevada. Boston, 1872. 292 pp.

KING, T. BUTLER. Report on the metallic and mineral wealth of California. Appendix to Taylor's El Dorado. New York, 1850.

KNEELAND, S. Wonders of the Yosemite Valley and of California. 97 pp. 2 maps. 10 photos.

KUSTEL, GUIDO. Concentration and chlorination of gold-bearing sulphurets, etc. San Francisco, 1868. 259 pp.

—— Roasting of gold and silver ores. New edition. San Francisco, 1880. 156 pp.

—— Nevada and California processes of gold and silver extraction.

LAUR, P. De la production des Metaux precieux en Californie. Paris, 1862. 132 pp.

—— Du gisement et de l'exploitation de l'or en Californie. In Ann. des Mines, Vol. 6, ser. 3, pp. 347–435.

LAUR, P. Terrains aurifères de la Californie. 20 pp. In Rev. d. Deux Mondes, Vol. 5, 1863, p. 453.

LE CONTE, JOSEPH. Elements of geology; a text-book for college and general readers. 2d edition. New York, 1878. 588 pp.

This work is of special interest to the student of California geology, containing many references to the geology of the State. We note an article on auriferous veins, given on p. 237; also, Quaternary period on the western side of the continent, p. 526.

LEVASSEUR, R. La question d'or, les mines de Californie et d'Australie, les anciennes mines d'or et d'argent. Paris, 1858.

LEVY, DANIEL. Les Français en Californie. San Francisco, 1884. 366 pp.

The second part of this book treats rather extensively of the placer mines, where they were located, how worked, etc. pp. 80 *et seq.*

LOCK, ALFRED G. Gold; its occurrence and extraction, etc. London, 1882. 1229 pp.

The description of the California gold fields is given on pp. 129–154.

MACFARLANE, JAMES. The coal regions of America; their topography, geology, and development; with a colored geological map of Pennsylvania, a railroad map of all the coal regions, and numerous other maps and illustrations. Third edition, with a supplement for the year 1875. New York, 1877. 697 pp., with maps, etc.

Chapter XXX treats of the Pacific Coast region. A description of the Mount Diablo coal field is given on pp. 563–567, with analyses of the coal.

MARCOU, JULES. American geological classification and nomenclature. Cambridge, 1888. 75 pp.

The author remarks on p. 44: "In California, the Cretaceous is limited to the northwest corner of the State, and occupies a small area west of Mount Shasta. The Geological Survey of California, directed by Mr. J. D. Whitney, has called Cretaceous all the Eocene of Fort Tejon and Chico Creek."

—— Geology of North America; with two reports on the prairies of Arkansas and Texas, the Rocky Mountains of New Mexico, and the Sierra Nevada of California, originally

made for the United States Government. Zurich, 1858. 144 pp. 7 plates and 2 geological maps.

This work contains:

Chapter I. Résumé of a geological reconnoissance extending from Napoleon, at the junction of the Arkansas with the Mississippi, to the Pueblo de los Angeles, in California. The following Californian fossils are described: Fossils of the Tertiary rocks—*Ostria Virginica*, var. *Californica*, Colorado Desert; *Spirifer striatus*, Mart., Shasta County, California.

Chapter V. On the geology of the United States and British Provinces of North America. Geological map of North America. (Extract from Dr. Petermann's Geographischen Mittheilungen, Heft. 6, in 4to. Gotha, 1855.) Contains a notice of the California Desert, or Great Basin, the Cascade Range, the Coast Range.

Chapter VI. Sketch of a geological classification of the mountains of a part of North America. (Extract from Annales des Mines, 5 ser., tome vii, p. 329. Paris, 1855.) Contains description of Coast Range and Sierra Nevada system.

Chapter VII. On the gold of California. (Extract from Bibliothéque Universelle de Genève. Février, 1855.)

MARIPOSA GOLD COMPANY REPORTS, by Garnet and Wakeley. 1863. 81 pp. col. map.

MARIPOSA ESTATE. London, 1861. 63 pp. map.

MARIPOSA ESTATE (THE), its past, present, and future. Comprising the official report of J. Ross Browne upon its mineral resources. Transmitted to Congress, March 5, 1868. New York, 1868. 62 pp.

MARRYAT, FRANK. Mountains and mole hills. New York, 1855. 393 pp.

This is an account of three years in California. Refers to the gold diggings on American River and other places, on p. 210 *et seq.*

MANLY, W. L. Death Valley in 1847. San José, 1894. 498 pp.

MANSON, MARSDEN. Geological and solar climates: their causes and variations. A thesis, University of California, May, 1893. San Francisco, 1894. 49 pp.

McGARRAHAN, WILLIAM. The quicksilver mines of Panoche Grande. Washington, 1860.

MEMORIAL of the New Idria Mining Company, in the matter of the Panoche Grande Rancho. 1867. 16 pp.

MINES AND MINING in El Dorado County. The mineral belt, its slates and ores; deep mining, principal mines, etc. San Francisco, 1882. 14 pp.

MOFRAS, DUFLOT DE. Exploration des Territoire de l'Orégon, des Californies et de la Mer Vermeillo, exécutée pendant les années 1840, 1841, et 1842. 2 vol. 8°, avec un Atlas in folio. Paris, 1844. Published by order of the King, under the auspices of the President of the Council and Minister of Foreign Affairs. Vol. I, 521 pp., 4 plates; Vol. II, 387 pp., 4 plates. Atlas of 26 sheets, maps, and plans.

This author states (Vol. 1, p. 489) that a vein of gold-bearing quartz was worked near the Mission of San Fernando by M. Baric in 1843.

According to De Mofras, the gold of the San Francisquito Rancho was first explored by M. Charles Baric. He gives its distance in the mountains as six leagues to the northward of the Mission of San Fernando, and fifteen leagues from Los Angeles. He further states: "This vein has an extent of six leagues, following the direction of the ravine where it is situated. The gold is found near the surface of the soil, and some pieces weighed two or three drachms." This description would lead one to the opinion that the deposit was a placer one and not a vein, although he uses the word *filon*.

According to De Mofras, silver ores occur about two leagues northwest of Cahuenga Rancho, and were not worked for want of mercury. He further observes that the Indians often bring in from the mountains, grains of copper, fragments of opal, and pieces of galena. Mines of gold and silver are also said to have been found about fourteen leagues from San Diego. They were once worked by a man from Guanajuata.

There is a notice of the bitumen near Los Angeles on p. 337, vol. 2. The author states: "Two leagues to the southeast of Los Angeles there are four great sources of asphaltum, situated on a level with the earth in a vast prairie. These springs open in the middle of little pools of cold water, while the bitumen possesses a higher temperature. This water has a mineral taste, which, however, does not prevent animals from drinking it. At sunrise the orifices of these springs are covered by enormous bubbles of asphaltum, often being more than a yard high, and looking like soap bubbles."

MOLITOR, A. P. Essay on California gold. San Francisco, 1860.

This work is said to be a very valuable essay on this subject.

MOWRY, SYLVESTER. The mines of the West. New York, 1864.

MUIR, J. Living glaciers of California. In Harper's Mag., Vol. 51, 1875, pp. 769–777.

MURCHISON, SIR R. Siluria: A history of the oldest rocks in the British Isles and other countries; with sketches of the origin and distribution of native gold, the general succession of geological formations, and changes of the earth's surface. 1st edition, London, 1854; geological map and 37 plates of fossils. 2d edition, London, ——. 3d edition, London, 1859; geological map and 41 plates of fossils. 4th edition, London, 1867; geological map and 42 plates. 5th edition, London, 1872; with geological map and atlas of 42 plates.

The author notes the California gold field on p. 470. He remarks in conclusion: "1. That, looking to the world at large, the auriferous veinstones in the lower Silurian rocks contain the greatest quantity of gold; 2. That where certain igneous eruptions penetrated the Secondary deposits, the latter have been rendered auriferous for a limited distance only beyond the junction of the two rocks; 3. That the general axiom before insisted upon remains: that all Secondary and Tertiary deposits (except the auriferous detritus in the latter) not so specially affected never contain gold."

NORDHOFF, CHARLES. California for health, pleasure, and residence: a book for travelers and settlers. New York, 1873. 255 pp.

Contains notice of gold mining, with a few geological notes.

OLD RIVER-BED GOLD MINING COMPANY. Report, 1879. New York. 18 pp.

The mines of this company are situated in Butte County, on the west branch of the Feather River. The report contains reports and sections, by J. H. L. Tuck and R. H. Stretch, on the old Pliocene river-beds of California, with sections of the west branch of Feather River, Butte County, California.

OREGON AND CALIFORNIA: Account of gold regions, methods of testing gold, etc. 1849. 76 pp. col. map.

PACIFIC COAST PETROLEUM COMPANY lands in San Luis Obispo County. 1865. 15 pp.

PALMER, GEN. WM. J. Report of surveys across the continent in 1867–68, on the 35th and 32d parallels, for a route extending the Kansas Pacific Railway to the Pacific Ocean at San Francisco and San Diego. Philadelphia, 1869. 250 pp. maps.

Contains a report by Dr. C. C. Parry, geologist and naturalist to the Survey, on the mineral districts of Central and Western Arizona and Southern California.

PFEIFFER, E. J. Sketch-map of the Forest Home and Willow Springs Copper Mining District, Amador County. San Francisco, 1864.

PHILLIPS, JOHN ARTHUR. Notes on the chemical geology of the gold fields of California. London, 1868. tract.

—— Gold mining and gold discoveries made since 1851. London, 1862. tract.

—— The mining and metallurgy of gold and silver. London, 1867. tract.

PHILLIPS, JOHN S. Explorers and assayers' companion; rocks, veins, testing, and assaying. 2 vols. San Francisco, 1879.

PLAYER-FROWD, J. G. Six months in California. London, 1872. 164 pp.

A sketch of the general geological features of California is given on pp. 48–57; of mines and mining, on pp. 85–108.

QUICKSILVER: Facts concerning mines in Santa Clara County, California. New York, 1859.

RAMOS, J. M. Informe relativo à los Trabajos ejecutados por la comision exploradora de la Baja California. Mexico, 1886. 222 pp. maps and geological sections.

RAVEN, RALPH. Golden dreams and leaden realities; with introduction by F. Fogie. New York, 1853. 344 pp.

RÉMOND, A. Report of an exploration and survey of the coal mines of Monte Diablo district. San Francisco, 1861.

Contains small sketch-map in black, showing Tertiary hills.

REVERE, J. W. (Lieut. U. S. Navy). A tour in California, including a description of the gold region and an account of the voyage around Cape Horn, etc. New York, 1849. 305 pp. maps and illustrations.

Chapter XIX treats of the gold regions. It also contains the official report of Colonel Mason, etc.

ROBINSON, FAYETT. California and the gold regions, with a geographical and topographical view of the country, its

mineral and agricultural resources, prepared from official and other authentic documents; with a map of the United States and California, showing the routes of the U. S. mail packets to California; also the various overland roûtes. New York, 1849. 137 pp.

Chapters I and II contain reports of the gold mines, with early accounts of the existence of gold in California.

This book also contains a synopsis of Mr. Larkin's and Colonel Mason's reports.

RUXTON, C. F. Life in the far West. New York, 1859. 235 pp.

SILVERSMITH, J. Metallic and agricultural wealth of the Pacific States. 1863. 150 pp. illustrated.

SEYD, ERNEST. California and its resources. London, 1858. 168 pp. maps.

Contains a chapter on gold mining, and references to other minerals; etc.

SEYMOUR, E. S. Emigrants' guide to the gold mines. Chicago, 1849.

SHALER, N. S. California earthquakes. In Atlantic Monthly, Vol. 25, 1870, p. 351.

SHAW, WILLIAM. Golden dreams and waking realities. Being the adventures of a goldseeker in California and the Pacific Islands. London, 1851. 316 pp.

SHINN, CHARLES H. Mining camps: a study on American frontier government. New York, 1885. 316 pp.

SILLIMAN, B. Petroleum region in California. 1864. 21 pp., with one plate.

—— Report upon the oil property of the Philadelphia and California Petroleum Company. Philadelphia, 1865. 36 pp.

—— On petroleum in California. National Intelligence, February 7, 1866.

SIMONIN, LOUIS. La vie Souterraine, ou les mines et les mineurs. Paris, 1867.

Contains Cartes des gîtes miniers des États de la Californie et Nevada.

SIMPSON, HENRY J. The emigrant's guide to the gold mines. New York, 1848.

SOLIGNAC, ARMOND DE. Les Mines de la California. Limoges, 1852. 98 pp.

This book is a narrative of the author's trip to California. There is very little about the mines, except on page 53, where he gives a short description of the placers on the American River.

STETEFELDT, C. A. The lixiviation of silver ores with hyposulphite solutions, with special reference to the Runell process. New York, 1888. 223 pp.

STEWART, W. M. Lecture on the mineral resources of the Pacific States. New York, 1865.

STILLMAN, J. D. B. Seeking the Golden Fleece. San Francisco, 1877. 352 pp. illustrated.

This work is in the shape of a journal. On page 157 the author gives an account of mines, etc.

STONE, R. C. Gold and silver mines of America. New York.

TAYLOR, BAYARD. El Dorado: Adventures in the path of empire. New York, 1850.

In the appendix there is a report of Hon. T. Butler King, on the metallic and mineral wealth of the State. pp. 201–247.

TAYLOR, R. C. Statistics of coal. The geographical and geological distribution of mineral combustibles or fossil fuel; including, also, notices and localities of the various mineral bituminous substances employed in arts and manufactures. Illustrated by maps and diagrams, etc. Philadelphia, 1848.

Under the heading of Upper California, the author states: "In the spring of 1847, a new coal mine was discovered near San Luis Obispo, N. Lat. 35°. There are now three mines within three hundred miles of Monterey. Asphaltum and petroleum occur abundantly in Western California."

—— *Same.* Second edition, revised and brought down to 1854, by S. S. Haldeman. Philadelphia, 1855.

Notes a report of Dr. Le Conte on the discovery of coal, 12 miles north of San Diego, in 1851.

TEGOBORSKI, M. L. DE. Essai sur les conséquences éventuelle de la déconverte des gites aurifères en Californie et en Australie. Paris, 1853. 199 pp.

THE PIUTE COMPANY OF CALIFORNIA AND NEVADA; organized April 13, 1869, incorporated June 30, 1870. San Francisco, 1870. 23 pp. 21 plates, and map.

This report contains excellent maps of the mining region, in San Bernardino County, California, and the adjoining Yellow Pine District, in Nevada. A few geological notes are given in the descriptions of the different mines.

THE NEW ALMADEN MINES. Letters from the San Francisco "Daily Herald," as published on the mornings of the 15th, 17th, and 18th of December, 1858. San Francisco, 1858. pamphlet.

THORNTON, J. QUINN. Oregon and California in 1848, with an appendix including recent and authentic information on the subject of the gold mines of California and other valuable matter of interest to the emigrant, etc. New York, 1849. 2 vols.

The appendix to Vol. 2, pp. 267-379, contains an account of the gold region of California, which is principally a copy of the official reports made in 1848.

TRASK, DR. JOHN B. Earthquakes in California from 1800 to 1863. San Francisco, 1864. 26 pp.

Dr. Trask also published several articles on the same subject in the Proceedings of the California Academy of Sciences.

—— Topographical map of the mineral districts of California, being the first map ever published from actual survey. San Francisco, 1853.

TRÉNY. La Californie dévoilée du vérités irrécusable appuyées sur le nombreux témoignages sur cette partie du globe. Paris, 1850. 60 pp.

This pamphlet was issued in three editions.

TRIPP, D. K. Report of the examination and survey of the Sonoma Pacific coal mines. Report 1888. San Francisco, 1888.

These mines are located about two and one half miles from Santa Rosa. The report gives several analyses of the coal, by D. K. Tripp.

TURRILL, CHARLES B. First volume—California Notes. San Francisco, 1876. 232 pp.

This book contains a chapter on the topography of California, with notes on the gold mines and geology of gold section.

TYSON, J. L. Diary in California. Baltimore (?), 1850. 92 pp.

UPHAM, SAMUEL G. Notes of a voyage to California via Cape Horn; also, scenes in El Dorado, 1849 and 1850. Philadelphia, 1878. 594 pp.

VEATCH, JOHN A. Letter from Dr. John A. Veatch to the Borax Company of California, June 28, 1857. San Francisco, 1857. 16 pp.

Dr. Veatch discovered borax at Borax Lake, Lake County, in 1856.

WALTON, DANIEL. Facts from the gold region. Boston, 1849.

WASSON, JOS. Bodie and Esmeralda. Being an account of the revival of affairs in two singularly interesting and important mining districts, including something of their past history, and the gist of the reports of Profs. Benj. Silliman and W. P. Blake, the late J. Ross Browne, R. H. Stretch, State Mineralogist, and H. R. Whitehill; also, detailed descriptions of mines most developed, tunnels, mills, etc. San Francisco, 1878. 60 pp.

WELLS, W. V. How we get gold in California. In Harper's Mag., Vol. 20, 1860, p. 598. 19 pp.

WERTH, JOHN J. A dissertation on the resources and policy of California: minerals, agriculture, and commerce, including a plan for the disposal of the mineral lands. Benicia, 1851. 87 pp.

WESTON, S. Four months in the mines of California. Providence, 1854.

WHITNEY, J. D. The metallic wealth of the United States described and compared with that of other countries. Philadelphia, 1854. 510 pp.

An account of the gold, with the geology of this region, in California, is given on pp. 134–149.

WHITNEY, J. D. Letter of Professor Whitney, State Geologist of California. In the Mariposa Estate, London, 1861, pp. 5–7.

WOODS, DANIEL B. Sixteen months at the gold diggings. New York, 1851. 199 pp.

The appendix contains a letter from Prof. Edward Hitchcock on the gold mines of California.

WRIGHT, G. F. The Ice Age in North America, and its bearings upon the antiquity of man, by G. Frederick Wright; with an appendix on the probable cause of glaciation, by Warren Upham. New York, 1889. 622 pp. maps and many illustrations.

The author notices the existing glaciers of California, ancient glaciers, the terminal moraines of California, the pre-historic man in California, ancient river-beds, etc.

WYLD, J. Guide to California. London, 1849.

—— Notes on the distribution of gold throughout the world, including Australia, California, and Russia. London, 2d edition, 1851; 3d edition, 1853.

—— Geographical and mineralogical notes to accompany Wyld's map of the gold regions. London, 1849.

YALE, GREGORY. Legal titles to mining claims and water rights in California. San Francisco, 1867. 452 pp.

This report gives the history of early mining legislation in the United States, and especially that of California.

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GLENN H. BOW

CALIFORNIA STATE MINING BUREAU.

J. J. CRAWFORD, State Mineralogist.

BULLETIN NO. 11. San Francisco, December, 1896.

OIL AND GAS YIELDING FORMATIONS

OF

Los Angeles, Ventura, and Santa Barbara Counties.

PART I.

BY W. L. WATTS, M.E.,
Field Assistant.

SACRAMENTO:
A. J. JOHNSTON, : : : : SUPERINTENDENT STATE PRINTING.
1897.

To replace
21519

LETTER OF TRANSMITTAL.

CALIFORNIA STATE MINING BUREAU,
SAN FRANCISCO, December 1, 1896.

To HON. J. J. CRAWFORD, *State Mineralogist:*

DEAR SIR: In accordance with your instructions of September 9, 1894, I have investigated such portions of the oil-yielding districts on the west side of the Coast Range, and south of the Sierra Madre range, as has been possible in the time at command. I hope to complete our investigations during the next two years.

In this bulletin the following oil-fields are described: In Los Angeles County, the Los Angeles City and the Puente oil-fields. In Ventura County, the Sespe district and the oil districts north of Santa Paula. In Santa Barbara, the Summerland oil-field and the petroleum-yielding formations in the southeast corner of the county. I speak only of localities wherein I have obtained geological evidence concerning the relation of the exposed rocks to oil-yielding strata.

Some of the streams and mountain peaks mentioned in this bulletin are not shown on the Land Office maps. In such instances, the names used are those by which such streams and peaks are best known locally. The facts stated, and deductions made, concerning the different localities mentioned, speak for the time at which such localities were visited.

Allow me to take this opportunity of returning thanks to the following gentlemen who have rendered valuable assistance in the work which is the subject of this bulletin: General K. H. Wade, G. W. Parsons, E. Wright; County Surveyor J. B. Hawley, C.E.; the officers of the Los Angeles City Waterworks; J. S. Maltman, President, and others of the Capital Crude Oil Co.; L. Stewart, President, and others of the Union Oil Co.; F. C. Garbutt; the officers of the Los Angeles Oil Exchange; Messrs. Doheny & Connon—(all of Los Angeles); G. C. Power, County Surveyor of Ventura County; A. S. Cooper, C.E., of Santa Barbara; H. T. Doulton and H. L. Williams, of Summerland, Santa Barbara County, and many other gentlemen of Los Angeles, Ventura, and Santa Barbara counties.

Yours respectfully,

W. L. WATTS.

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THE OIL AND GAS YIELDING FORMATIONS

OF

Los Angeles, Ventura, and Santa Barbara Counties.

BY W. L. WATTS, FIELD ASSISTANT.

PART I.

LOS ANGELES COUNTY.

CHAPTER I.

Geology, List of Wells, Production, Etc.

1.1.01.* The most important mining operations in Los Angeles County are connected with petroleum; the total output for 1895 was 979,695 bbls., and the price realized was $732,817. The oil-fields which contributed to this total are situated at Los Angeles, in the Puente Hills, and in the mountains to the south and west of Newhall. They are known, respectively, as the Los Angeles, the Puente, and the Pico oil-wells.

1.1.02. The rocky formations at Los Angeles and its immediate vicinity consist of sedimentary strata, except a little decomposed granite rock, which is said to have been struck by the Los Angeles Water Co., when excavations were made for a reservoir at Ivanhoe. Beneath the surface soil of Los Angeles the most recent formations consist of sand drift and conglomerate, as may be seen in cuttings near the Sand Street school, on Brooklyn Avenue, and at other places.

1.1.03. These recent strata are practically horizontal, and rest nonconformably on formations of Pliocene age, which in most parts of the city are inclined at an angle of more than 20°. A large portion of these Pliocene formations consists of thin-bedded sandstones, sandy clays, and shales. This formation can be recognized in many of the street-cuttings by a yellow color, imparted to it, in most instances, by a sandy clay which is used in the manufacture of brick. There is also a soft, white, diatomaceous rock which belongs to this formation; it gen-

*The numbers at the beginning of the paragraphs are so arranged that the first figure denotes the *Part*, the next the *Chapter*, and the last two the *Paragraph*. Thus, 1.2.15 means the 15th Paragraph of Chapter II of Part I.

erally shows a calcareous reaction, and in some places it is mixed or interstratified with sand or clay. A few thin strata of this rock can be seen in a cutting about 300′ west of Fifth and Main streets. It is noticeable among sandy and clayey strata on Orange, near Alvarado Street, and in a ravine a short distance south of the old Dryden well. In a cutting on First and Olive streets, there is a rock which appears to be of a similar composition. At the first two places the rock is calcareous, but at the last two it is not. The yellowish formation is also found on the east side of the Los Angeles River, and patches of what appears to be a similar formation can be seen on the hills to the north of the city.

1.1.04. In the Farmdale school district, a formation very similar to the soft white rock already described, but possessing a distinctly shaly structure, is found, and in some places it appears to contain the impression of plants. Fossils were obtained from the sandy and clayey formation in the Normal School grounds at Los Angeles, and specimens from a similar formation at the Shatto estate on Orange, near Whitmer Street, were collected by Mr. W. Whitney and presented by him to the State Mining Bureau. Other specimens have also been loaned the Bureau by Mr. F. Forrester, which were collected by him at the following places: the Normal School grounds, the Shatto estate, and from a cutting on Sixth near Sumner Street. These specimens show that the rocks which held them are of the Pliocene age. (See table of fossils at end of this bulletin.)

1.1.05. It is the yellowish sandy and clayey formation which is penetrated by the numerous oil-wells at Second-Street Park, although it is possible that the deepest wells there may have gone through into older rocks. There are three places where glimpses may be had of the strata probably underlying the yellowish sandy and clayey formation:

(*a*) On First Street, near Rosemont Avenue, where there is an outcrop of oil-yielding shale, which shows a very slight dip to the north;

(*b*) Near the Dryden old well, where thick strata of sandstone dip S. 20° W. at an angle of 45°; about 300′ south of this sandstone thin strata of soft, clayey sandstone and shale are found dipping S. 20° W. at an angle of about 30°. The Dryden old well was sunk many years ago. It now shows a pit full of heavy oil with gas bubbling through it. It is said that formerly there was a large deposit of brea around this well, but that nearly all has been carried away for fuel;

(*c*) Along the creek which flows through the Maltman tract, where there are, at intervals, the following rock exposures: First, yellow clayey and sandy formations which dip S. 39° W. at an angle of 24°. A short distance farther northeast there is a soft, whitish, calcareous shale and clayey and sandy formation which dips S. 24° W. at an angle of 25°. Still farther north a light-brown bituminous sandstone crops out; dip S. 20° W. at an angle of about 20°. Still farther north there is a sandy bituminous shale dipping S. 32° W. at an angle of about 20°. The foregoing appears to be the order of their downward vertical range.

1.1.06. The Maltman wells are situated in the sandy bituminous shales. There are nine of them, and they vary from 140′ to 285′ in depth. They are all within a radius of about 300′ and range irregularly along a line running S. 7° W. The strata penetrated consist of sandy shale and oil-soaked sand, with a few thin strata of harder rock. One well is 16″, and the rest are 7″ and 8″ in diameter. There is a slight

flow of oil from one of them, and from another a small stream of water flows, which is accompanied by a light oil. Several of the wells yield a little gas. One of these wells was dry for the first 60′ of its depth, and among the material thrown out are numerous fragments of thin calcareous shale, similar to that seen beneath the yellow clayey sandstone on First Street near Rosemont Avenue. By pumping the Maltman wells they can be made to yield very nearly 2 bbls. of oil apiece, daily. At these wells there is a deposit of brea, and heavy oil exudes from shallow excavations therein. One excavation shows brea interstratified with alluvium to about 16′ in depth, the brea aggregating about 6′ in thickness. This brea is used for fuel to a limited extent, and is sold at the rate of $1 50 to $2 00 a ton on the dump. The Ruhland wells are about half a mile west of Westlake Park. There are twelve of these wells, which vary from 40′ to 100′ in depth. They are 7″ wells, and are said to have yielded, all told, about 4 bbls. of oil daily by bailing.

1.1.07. The formation exposed near the Ruhland wells is a sandy shale, which dips S. 22° W. at an angle of 65°; and in some places it is nearly vertical and faulted. There is much brea around the wells. A short distance northeast from the Ruhland wells there is another exposure of sandy bituminous shales, with what appears to be a thin remnant of a sandy, fossiliferous formation resting unconformably on them. Moreover, the sandy shale is pierced by boring, shells showing that it must have been an ocean-bed at the time of the deposition of the overlying rocks. It must be borne in mind that, although these shales are much disturbed, the prevailing direction toward which they dip corresponds to the direction of the prevailing dip of Pliocene strata which are exposed farther to the eastward; and the only marked nonconformity observed elsewhere in West Los Angeles is between Pliocene and much more recent formations. The fossils obtained from the sandy formation previously mentioned were in rather a poor state of preservation; one of them was found to be a well-marked Pliocene form, and the others ranged from living to Pliocene. All the fossils obtained in West Los Angeles appear to belong to the same geological horizon, namely, the Pliocene. Their vertical range is:

Living, Quaternary	5
Living, Quaternary, Pliocene	12
Living, Quaternary, Pliocene, Miocene	13
Quaternary	1
Quaternary, Pliocene	3
Pliocene	5

1.1.08. At the point northeast of the Ruhland wells, where the fossils were obtained, there is another bed of brea through which a well has been sunk, which is full of heavy oil. Toward the hills which lie to the north of the Maltman tract, for more than a mile, the rock exposures are poor, and are few and far between; but here and there yellow clayey sandstones are seen, and at one place there is a hard micaceous sandstone, and at another a soft bituminous sandstone crops out. At the only point where observations on the dip could be made, it was found to be less than 10°. There is also a seepage of heavy oil about half a mile northeast of the Maltman wells.

1.1.09. At Ivanhoe, the rock exposures are poor, but some strata are found dipping in a northeasterly direction. The formation is sandstone, interstratified in places with calcareo-silicious rock. The higher portion of the hills which extend from Ivanhoe to the Los Angeles River is com-

posed, for the most part, of older and harder rocks than those previously mentioned; although there are patches of the yellow sandy formation before referred to. The most characteristic rock is a hard, white calcareous shale, passing into fissile limestone. This rock can be traced from Ivanhoe to Lookout Mountain, in Elysian Park.

1.1.10. Throughout the northern summits of these hills the formation is mainly sandstone, with hard strata of calcareous rock, and the prevailing dip is still southwest, in most places at an angle of more than 40°. This sandstone formation is of great thickness, as may be seen by walking from the Buena Vista bridge along the flume of the Los Angeles Water Co. This flume runs at an angle of about 45° to the direction of the prevailing dip of the formation, which is S. 20° W. at an angle of from 30° to 50°. The calcareous rocks here referred to contain the remains of fish, but no specimens were found which were perfect enough for identification; nor were any fossils obtained by which the geological horizon of these older and harder rocks might be determined.

1.1.11. In the Hunter tract, on the east side of the Los Angeles River, the physical appearance of the exposed rocks resembles that of the rocks at Ivanhoe and some portions of Elysian Park. Especially is this the case with regard to the hard calcareous rocks previously described. On the Clark estate, in the Hunter tract, there are dark-colored shales containing *Pecten pedroanus*, Trask; *P. peckhami*, Gabb—Pliocene, Miocene.

1.1.12. On the east side of the Los Angeles River, both in the city itself and thence toward Pasadena, the formation is much more broken than it is on the west side of the river. There are no producing wells east of the Los Angeles River in the territory shown in the accompanying sketch map, Fig. 30.

1.1.13. West of Los Angeles a thick deposit of alluvium covers the valley lands and the foothills of the Cahuenga range of mountains. The rocks forming the axis of this range are granitic. The sedimentary rocks which overlie the granite are principally sandstones, from which a few Miocene and Pliocene fossils were obtained, notably in Brown's Cañon. In Hay's Cañon, west of Cahuenga Pass, the sedimentary rocks show metamorphism and contain a few fossils which are referred to the Eocene period by Dr. Cooper. The rocks exposed along the shoreline west of Santa Monica are similar in appearance, and probably belong to the same geological horizon as the rocks exposed at Los Angeles. The most recent formation consists of nearly horizontal strata of conglomerate and soft sandstone, which rest nonconformably on more compact conglomerate and sandstone. East of the pier the more compact sandstones are traversed by calcareous strata containing fossils which show the following range:

Living, Quaternary	2
Living, Quaternary, Pliocene	3
Living, Quaternary, Pliocene, Miocene	1
Quaternary, Pliocene	1
Pliocene	1
Pliocene, Miocene	1
Miocene	1

1.1.14. These sandy formations rest apparently somewhat nonconformably on shaly strata, which are much crushed, and in some places are composed of thin-bedded strata, which show a rapid transition from brown to white or light-colored material. Farther west, and

FIG. 2. CONTORTED STRATA IN TEMESCAL CAÑON, N.W. OF SANTA MONICA.

FIG. 3. PUENTE OIL-WELLS, LOS ANGELES COUNTY, LOOKING WEST.

evidently belonging to the same geological horizon, are soft, thin-bedded micaceous sandstones and sandy shales, interstratified with what appears to be infusorial earth. This formation is much crushed, and bleaches on exposure. The prevailing dip is N. 25° E.

1.1.15. At the mouth of Temescal Cañon, the bluffs are formed of the last two formations described; these are interstratified with flinty limestones. There is much contortion of strata, but the prevailing dip is N. 25° E. Resting conformably on these rocks is a coarse sandstone formed of granitic material and containing Pliocene fossils. In Temescal Cañon there are many rock exposures showing curiously contorted strata as in Fig. 2. In this cañon, Mr. C. H. Lenton has run three tunnels on strata of shale containing bituminous matter.

1.1.16. At Los Angeles the rocky formations constitute a portion of the southern slope of an anticlinal fold, which appears to extend eastward from the Cahuenga Mountains. The axis of this fold, although ill-defined, can be found a short distance north of Elysian Park. The prevailing dip of the strata forming the southern slope of this anticline is a little west of south, modified by subordinate folds or flexures, which in some places have locally inclined the strata in an opposite direction. There are two such flexures: one to the north and the other to the south of the oil-wells at Second-Street Park. Owing to the alluvium covering the rocks, only glimpses of these lines of disturbance can be obtained, but a careful study of them leads to the conclusion that they can be traced as follows:

1.1.17. The most important line of disturbance can be traced with a course S. 55° E. from the corner of Vermont and First streets to a point a little south of First and Glassel streets; thence to a point on Quebec near Ocean View Avenue; and thence to another point about 300′ north of Fourth and Bixel streets. The other line of disturbance can be observed on Burlington near Temple Street. It can be traced to Temple Street near Lake Shore Avenue, and probably the disturbance of the formation near Bellevue and Victor streets is associated with it. A little disturbance can be noticed in the middle of the oil-field on Court, near Toluca Street.

1.1.18. The history of the Los Angeles oil-wells, or more properly speaking, of the Second-Street Park oil-field at Los Angeles, is as follows: For many years a small deposit of brea was known to exist on West State Street near Douglas Street, in the City of Los Angeles; and the brea was locally used for fuel. In 1892, Messrs. Doheny & Connon sunk a 4′x 6′ shaft, 155′ deep, at the corner of Patton and State streets, close to the deposit of brea previously mentioned. The formation penetrated is sandy shale with a few thin strata of silicious or calcareous rock. Near the surface the oil was very heavy, but at about 7′ deep it was found to be lighter, and it seeped from the sides of the shaft. The oil exuded from porous material and from the surface planes of the hard strata. The formation was found to dip toward the south at an angle of about 40°. Excavation below a depth of 155′ was prevented by gas. An 18″ hole was then drilled in the bottom of the shaft, and yielded 7 bbls. of oil daily for several weeks. In July, 1894, the yield had decreased to 2 bbls. of oil a day. In November, 1892, an oil-well was sunk at Second-Street Park by Messrs. Doheny & Connon. As soon as this well was found to be a success, other wells were sunk on adjacent lots, and the Second-Street Park oil-field grew rapidly. By the end of

1895, there were more than 300 wells within an area of less than 4,000,-000 sq. ft. During 1895, the price of crude oil at Los Angeles fell to a ruinously low rate, the average price for that year being about 60 cents a barrel; indeed, there were sales at a much lower rate, it is said even as low as 25 cents a barrel. The reason of this depression was the lack of coöperation among the oil-producers and the lack of facilities for storing and handling the oil. Early in 1896, the price of oil commenced to recover, and in July, 1896, it had reached $1 a barrel. The reason of this recovery was the diminishing of the supply, the organization of the oil-producers, and the increased facilities for storing and handling the oil.

1.1.19. The rock penetrated by the oil-wells at Second-Street Park consists of soft, thin-bedded sandstones, and sandy clays and shales, which are interstratified by thin strata of impure limestone and calcareous strata and two or more strata of oil-bearing sand. This formation is of Pliocene age. At least, as before mentioned, all the fossils obtained from the outcropping rocks in the Los Angeles oil-field and elsewhere in Los Angeles are of that age. The principal stratum of oil-bearing sand is about 150′ thick, and it crops out at the surface on Burlington Street, about 300′ north of First Street. As a typical illustration of the character of the strata penetrated by the oil-wells at Second-Street Park, Mr. Doheny states that wells drilled by the Doheny Oil Co., in the northeastern portion of the oil-field, pierce the following formations:

Sandy and clayey strata, with thin strata of hard rock	650′
Oil-sand, interstratified with sandy clay	125′
Tough clay (putty)	200′
Oil-sand, with water	3′
Sand, with water	undetermined.

The oil-sand is more than 100′ thick, the richest portion of it being about 45′ thick. Mr. Doheny states that the dip at which he struck the oil-sand in most of his wells shows that in the portion of the field in which his wells are situated the prevailing dip is at an angle of about 40°, but that the angle of inclination is by no means uniform; the latter inference is corroborated by the experience of others, as hereinafter noted.

1.1.20. In other portions of the field the following formation has been penetrated:

Adobe soil	6′
Yellow clay	20′
Tough blue clay	20′ to 30′
Clay shale, with thin strata of sand and hard calcareous strata, "shells"	200′ to 700′
Oil-sand	70′ to 145′

1.1.21. Fig. 4 represents a section across the west end of the oil-field at Second-Street Park. It shows the lines of geological disturbance to the north and south of the oil-field, the outcrop of the oil-sand, and the point where it is penetrated by a well sunk by Mr. Garbutt, near the corner of First Street and Union Avenue. Up to April, 1896, this well was the farthest west of any productive one in the district. In this well, the oil-sand was struck at about 855′ deep, which shows that at this end of the field the angle of the dip of the oil-sand must be about 45°. This angle is very nearly that of the dip of the formation exposed near Mr. Garbutt's well, but more than that of the oil-sand where it crops out at the surface of the ground on Burlington Street. On the

ıt-hand side of the diagram is the south line of disturbance, notice- › on Quebec Street. If this line is followed along its strike, it would ›s Western Avenue near Silver Street. It has been necessary to ɛe the lines of disturbance well marked on this diagram, but on the 'ace of the ground they are merely indicated by strata dipping in osite directions. On Burlington Street, about 300′ north of First ›et, is the only place in the Second-Street Park oil-field where the

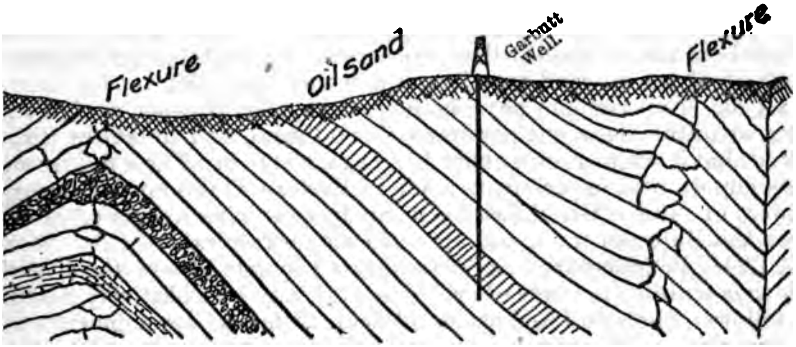

FIG. 4.

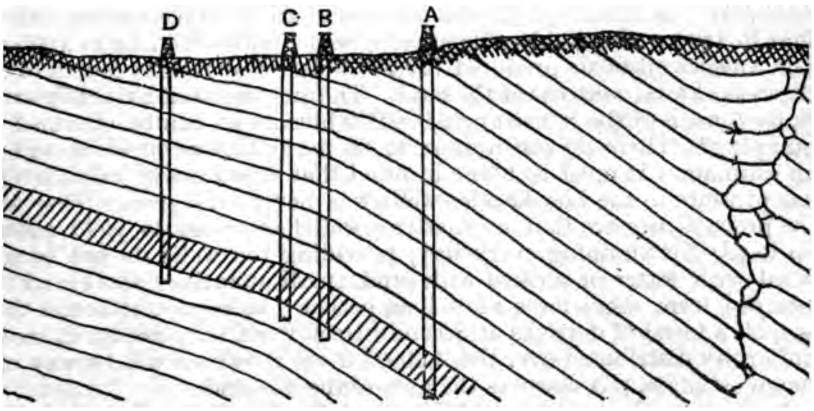

FIG. 5.

A.—Union Oil Co.'s well on First Street.
B.—American Crude Oil Co.'s well.
C.—Cole's well.
D.—American Crude Oil Co.'s well.

ds were observed cropping out. The reason of this may be explained Fig. 5.

.1.22. In well A, on the south side of First Street, the oil-sand was ıck at a depth of 1,010′. If a line be drawn from this well across oil-field, and at right angles to the prevailing strike of the formation, ch is S. 80° E., and if the wells nearest thereto, of which information ld be obtained, are arranged at points where the strike of the strata ɪ penetrate cross the line, the profile shown in Fig. 5 is obtained. m oil-sand in well A to oil-sand in wells B and C, the dip is shown

to be at an angle of about 35°. From oil-sand in well C to oil-sand in well D, the dip shown does not exceed an angle of 16°. With the oil-sand dipping at this low angle it could not come to the surface before reaching the line of disturbance noted in the north end of the field. In wells drilled along the north and south margins of the oil-line, water has been troublesome and has prescribed the width of the oil-bearing territory. The operators in the Los Angeles oil-fields agree that the main stratum of oil-sand thus far explored is from 100′ to 150′ thick, but that, as a rule, it is not productive all the way through. The general opinion of well-drillers appears to be that on an average at least 40′ of the oil-sand may be put down as "pay dirt."

1.1.23. Experiments have been made by Mr. Hawley, a civil engineer, as to the absorbent powers of this oil-sand, and he states that he found that it would absorb about 10% of oil of 14° B. These figures agree very closely with experiments made in Eastern States on the absorbent powers of sand. Mr. Doheny also made some experiments on oil-sand from the Maltman tract, and obtained higher results.

1.1.24. For the purpose of obtaining a concrete idea of the situation which is within the range of probability, it may be tentatively admitted as follows: That the Los Angeles oil-field, as far as developments have shown, derives its oil from a stratum of sand carrying about 10% of oil; that the said stratum is about 40′ thick, and has an area of about 4,000,000 sq. ft. Such a stratum would contain, in round numbers, about 2,850,000 bbls. of oil. A careful canvass of all the oil-producers shows that in 1894 no inconsiderable amount was produced, while in 1895 the Los Angeles oil-fields produced 729,695 bbls., or about one fourth of our theoretical total contents of the sand. The question that naturally arises is, how much of the remaining 2,000,000 bbls. of oil can be obtained by pumping? There do not appear to be many factors on which to base an estimate. It must be borne in mind that it is a heavy oil; that the gas pressure in the Los Angeles wells was never very great. Therefore, the probabilities are that, even after a well has ceased to yield enough oil to pay for pumping every day, providing the wells do not become filled with water or choked with sand, small quantities of oil might be pumped from them for quite a long period. Moreover, although there is such a forest of derricks at Second-Street Park, they are by no means uniformly distributed over the 4,000,000 sq. ft. which we, by way of a rough estimate, put down as the area of the oil-sand.

1.1.25. In the beginning of March, 1896, there were about 330 wells in the oil-field. Allowing to each well, say 5,000 sq. ft., as they were distributed at that date, it would seem that there must be more land in the area we calculated yet to be heard from. Much of the unbroken territory is covered by streets and buildings; this is all the better for the wells which are near them; but it seems probable that if a reasonable price can be maintained for the oil, wells will yet be sunk at Second-Street Park, which may yield moderate returns.* The question naturally suggests itself, cannot other strata of oil-sand be found by drilling to a greater depth than has yet been reached? The experiment is worth trying, but the only wells which in April, 1896, had gone far below the main oil-sand have encountered water. With the limitation of the Second-Street Park oil-field thus in sight, the question as to the

* These remarks are based on observations made in 1895.

extension of the oil-field becomes one of great moment, and the only plan is to follow the strike of the formation which has proved to be oil-producing. As indicated by the arrows in the geological sketch map of West Los Angeles, Fig. 31, the prevailing dip of the formation, as seen at the surface, is S. 10° W., although there are numerous aberrations from that azimuth. The depth at which the oil-sand was struck in the different wells leads to the conclusion that, in the main, the strike and dip of the oil-sand are similar to those of the rocks exposed at the surface. The general direction of the oil-line, as indicated by the productive wells, is practically east and west. Disregarding any faults there may be in the rocky formation, which for the most part is covered by alluvium, an inspection of the geological map of Los Angeles leads to the following conclusion: If the oil-line on which Second-Street Park oil-field is situated be extended westward it would pass a short distance south of the Baptist University. Southwest of the university grounds a formation is exposed which corresponds very closely to that at Second-Street Park. This formation rests on a series of sandstones, several strata of which are oil-bearing. On the Maltman tract these sandstones, which show a thickness of several hundred feet, are penetrated by nine wells, ranging from 140′ to 285′ in depth. Each of these wells, as before mentioned, can be made to yield something less than 2 bbls. of heavy oil a day. In all the deeper wells water was encountered. It is evident, therefore, that the oil-yielding formations extend westward from the Second-Street Park oil-field. The only attempts that have been made to prospect the territory between the Second-Street Park and the Baptist University are as follows: The Fudicker well, situated south of First Street and near what would be Reno Street if it were graded; the Union Oil Co. well, situated south of First and west of Alvarado Street; one known as the old Dryden well, which is about 1,000′ northwest of the preceding, and one sunk by Mr. Doheny, near the corner of First and Newhall streets. All of these wells proved unsuccessful and are abandoned; the cause assigned for the failure of the first two being water or water and quicksand. Farther south, near Westlake Park, is the Wilshire well, which was unsuccessful; and farther west there are a very few shallow wells, like the Ruhland, which have yielded small quantities of heavy oil. From the record of these wells, the outlook to the west does not seem encouraging. A careful inspection of the territory, however, leads to the conclusion that the Doheny and the Union Oil Co.'s wells are the only prospect wells mentioned that penetrate similar strata to those which yield the oil at Second-Street Park; that the Doheny well must be nearly on the outcrop of the oil-sand, and that probably the well of the Union Oil Co. is not very far south of it. In the northeast end of the Second-Street Park oil-field, the exposed rocks on Bellevue Avenue, near Victor Street, give evidence of geological disturbance, which probably accounts for the fact that some wells in this portion of the oil-field have proved unsuccessful.

1.1.26. At first sight the steep dip of the formation, as seen near the corner of Beaudry and Bellevue avenues, is very disheartening, for the continuation of so steep a dip would restrict the field to a very narrow oil-line. Investigations farther to the eastward, however, show that this is not the case. Rock exposures on Bartlett Street, near Pearl, show a dip of a little west of south at an angle of about 25°, which leads to the

conclusion that the steepness of the dip near the corner of Beaudry and Bellevue avenues is but local. There does not appear to be any reason why the oil-yielding formations should not be followed east from Second-Street Park, but between it and the Los Angeles River there are very few opportunities of examining the rocky strata. It is a noteworthy fact, however, that in the water-wells which penetrate the drift near the Main-Street bridge, traces of oil contaminate the water.

1.1.27. The Brook or Chandler well, and the Hoag & Silent well, situated in the north edge of De Soto Heights (see Fig. 30), must be very nearly on the strike of the formation penetrated by the oil-well at Second-Street Park, but they appear to be abandoned. It is said that heavy oil was obtained in the Brook well, but that it was impossible to case off the water without also casing off the oil. Several enterprising citizens have drilled wells in an endeavor to find other oil-lands in the vicinity of Los Angeles, but without success; in nearly all these wells the strata penetrated showed small quantities of oil. It is said that the cause of failure, in most instances, was water, or water and quicksand.

1.1.28. From the foregoing it appears that an extensive oil-yielding formation underlies a portion of Los Angeles; that up to date explorations outside of the Second-Street Park oil-field have not been successful. A review of the situation leads to the conclusion that the best results will be obtained by following the strike of the productive oil-yielding formation rather than by sporadic prospecting. When a point is reached where the formation is broken, in the absence of any rock exposures to prove that the geological disturbance is other than local, several hundred feet should be passed over and prospecting be re-commenced still in the direction of what had been previously proven to be the strike of the oil-yielding rocks. Accurate drilling records should be kept, from which a profile of the oil-yielding strata might be made, and by which an engineer could trace the course of the oil-sand. In view of the fact that the direction of the strike and the angle of the dip are somewhat irregular, the safest mode of procedure is to progress gradually and not make too long jumps.

1.1.29. One interesting feature of the Los Angeles oil-field is that the oil from the upper strata is usually of a less specific gravity than that from the lower strata. Thus, there are instances in the Los Angeles oil-field where the specific gravity of the oil increased with the depth according to the following ratio:

At a depth of 300′ the specific gravity of the oil was 20° B.
At a depth of 700′ the specific gravity of the oil was 19° B.
At a depth of 900′ the specific gravity of the oil was 16° B.

This is the reverse of the usual experience with oil-wells.

1.1.30. The cost of wells in this oil-field has been remarkably small. The drilling of a 1,000′ well has been sometimes contracted for less than $1,000, and the cost of a plant for operating a well need not exceed $1,500, and indeed is frequently less.

LAR STATEMENT OF LOS ANGELES OIL-WELLS, FOR THE YEAR 1895, AS FURNISHED BY OWNERS OR AGENTS.

Name and Address of Company.	Number of Wells.	Depth. Feet.	To First Sand. Feet.	Specific Gravity.	Product of 1895. Bbls.
, H. B.	2	550			700
on, J. H., 1807 S. Hope Street	4	700		16.0° B	10,000
an Crude Oil Co., Byrne Building	5	770 to 925	730 to 855	15.5° B to 14.5° B	30,000
& Last	6	700 to 800		15.0° B	25,000
& Bentz	3	1,100			
		965		15.0° B	12,000
		986			
Young & Cochran, 260 Galena Ave., dena	2	840	700	13.0° B	100
		800	None		
Mrs. Cora A., 149 Kern Street	1	977		14.5° B	1,200
& Co., G. W., 309 Figueroa Street	1	840	820		1,500
r, Forst & Tabor, Edgeware and Omaha	2	742	715		5,000
		765	690		
r, Morris & Blaisdell, care Savings Bank ust Co.	2	805	665		4,000
		775	640		
John, Court Circle	2	950			
		880			20,000
Hill Oil & Coal Co., 338 S. Broadway	1	911	900	13.5° B	None.
er (new well)	1	810	770		95
W. H. E., 1532 Rockwood Street	1	955	600	16.0° B	1,200
o Crude Oil Co., 309 S. Hope Street	2				None.
J. R., 2433 Grand Avenue	1	700	350	18.0° B	1,800
W., care L. A. National Bank	1	650	650	19.0° B	1,600
., Belmont and First Streets	2	900	825	15.5° B	3,000
nation Oil Co., 1319 Omaha Street	4				7,000
idated Oil Co., 305 State Street	2	1,035		14.0° B	7,000
		1,000			
ell Oil Co., 341 Edgeware Road	4	700	700		
		750	750		
		750	750		
		906	750	16.0° B	6,000
K. P., 213 Nolan & Smith Block	8	1,025			
		952			
		981	650	15.5° B	5,000
& Fletcher, 1342 Calumet Avenue	3	900			
		788			
		930		15.0° B	5,000
Cook & Co., care Chamber of Com.	1	1,000	400	17.0° B	5,000
on, Melice & Co., Byrne Building	2	830			
		835	730	15.5° B	7,000
Sloan & Beers, 320 Park Place	4				1,500
. C., 826 Buena Vista Street	1	930		14.5° B	3,000
nd Oil Co., 147 S. Broadway	3			16.0° B	5,000
y-Connon Oil Co., Stimson Block	28				100,000
n, W., University Post Office	2	750			
		989	660		6,000
May & Mernier, 1525 Rockwood Ave.	1	810		18.0° B	1,000
de Oil Co., 530 Stimson Block	2	900			
		900	740	16.0° B	1,000
rth & Griggs	9	1=890	750	16.0° B	8,000
		6=650			
ly & Stack, 132 S. Broadway	2	865		16.0° B	6,000
ly & Stack	1				4,000
e Oil Co., 130½ S. Spring Street	4	893	790		
		740	660	14.5° B	
		860	790	to	
		840	770	16.5° B	15,000
a Oil Co., 302 Smith & Nolan Block	5	800 to 950			5,000
on & Canfield, 373 N. Main Street	3	950	800	15.0° B	
		950	800	15.0° B	
		850	745	14.0° B	2,200

TABULAR STATEMENT—Continued.

Name and Address of Company.	Number of Wells.	Depth. Feet.	To First Sand. Feet.	Specific Gravity.	Product of 1895. Bbls.
Ferguson, Mrs. M. L., 5 Phillips Block	1	800	-------	-------	1,500
Fowler, R. A., 115 W. Second Street	1	820	760	15.0° B	2,000
Frendberger, P., 321 Metcalf Street	2	620	-------	-------	-------
		620	-------	16.0° B	None.
Green, R., 811 Bonnie Brae	2	915	-------	-------	-------
		907	-------	-------	None.
Greenwood & Barkelow, Toluca and First Sts.	2	475	-------	-------	-------
		715	-------	15.0° B	2,000
Guiteau, H. C., 142 W. Twenty-fifth Street	2	800	-------	16.0° B	3,500
		758	-------	-------	-------
Haight, Webster & Co., 401 N. Figueroa St.	1	935	780	15.0° B	5,000
Hall, Charles Victor, 220 Central Avenue	3	900	-------	-------	-------
		900	-------	-------	-------
		750	750	16.0° B	8,700
Harrison, H. H., 316 Park Place	1	860	820	15.0° B	3,000
Henderson, F. B. & Co., 516 Bradbury Block	3	700	-------	-------	-------
		960	-------	-------	-------
		970	-------	-------	2,300
Hibbard & Co., 340 S. Edgeware Road	2	760	-------	-------	-------
		815	-------	-------	7,500
Hoffman & Weller, 109 N. Main Street	3	750	700	-------	-------
		850	700	-------	-------
		950	700	14.5° B	4,000
Home, J. K., 1354 Court Street	1	650	-------	19.5° B	2,000
Johnson, M. D., 216 W. First Street	4	800	-------	-------	20,000
Keating Oil Co., 945 Pasadena Avenue	2	981	950	-------	-------
		1,015	975	-------	1,800
Lake Shore Oil Co., 20 Schumacher Block	1	800	-------	17.0° B	1,500
Lathrop, Chas., 1017 Temple Street	2	750	-------	-------	-------
		850	-------	17.0° B	20,000
Lawrence, Geo., 20 Potomac Block	3	710	-------	14.0° B	-------
		745	-------	14.0° B	-------
		843	-------	14.5° B	3,500
Lehman & Mills, 213 S. Spring Street	4	950	810	15.5° B	12,000
Lewis, Mrs., 161 Lake Shore Avenue	2	700	-------	16.0° B	5,500
		900	-------	-------	-------
Libby, C. H., 340 S. Edgeware Road	2	750	-------	-------	-------
		800	-------	15.0° B	3,500
Lohma Oil Co., W. Lacy, Pres., 4 Baker Block	11	-------			40,000
L. A. Con. Oil Co., Court and Patten	1	720	675	16.0° B	2,000
Luitweiler, S. W., 200 N. Los Angeles Street	2	1,050	1,020	13.0° B	1,500
McCabe, Frank, 302 First Street	4	700	-------	-------	-------
		to 1,140	700	18.0° B	-------
McGray & Warring, Temple and Park Place	3	840	-------	-------	-------
		850	-------	15.5° B	13,400
McGary & Reed, 227 W. Second Street	2	800	750	16.0° B	500
McGee, E. M., Lake Shore and State	1	830	770	-------	2,100
McIntosh, 207 Bradbury Block	1	811	750	-------	1,500
Maier & Zobelein, 444 Aliso Street	3	800	-------	16.0° B	7,000
Manatt, Rich & Schall, 546 Ruth Avenue	2	765	-------	17.0° B	3,000
		850	-------	-------	-------
Martin, A. E., 142 Court Street	4	850	-------	18.5° B	13,400
Mathay, F. L., 1327 Court Street	3	840	-------	-------	-------
		800	-------	-------	-------
		800	-------	16.0° B	12,000
Nelson, R. T., 176 Bonnie Brae	2	860	-------	-------	-------
		825	740	15.5° B	12,000
Neubauer, J., 1579 Rockwood Street	1	890	890	15.0° B	8,000
North, Edward, 1127 Temple Street	2	840	780	-------	-------
		850	770	-------	7,198
O'Reilley, Mrs. Zella, 631 Washington Street	4	600	-------	-------	-------
		630	-------	-------	-------
		757	600	17.5° B	3,000
Orr & Patterson, 147 N. Spring Street	2	600	-------	-------	-------
		600	-------	16.0° B	1,200
Osborne & Stoll, 9 Metcalf Street	2	800	-------	-------	-------
		800	-------	16.5° B	8,000

TABULAR STATEMENT—Continued.

Name and Address of Company.	Number of Wells.	Depth. Feet.	To First Sand. Feet.	Specific Gravity.	Product of 1895. Bbls.
: Union Oil Co., 115 W. Second Street	2	790			
		675			5,000
·, L. C., 136 S. Broadway	3	895	1st sand	=20.0° B	
		1,005			
		1,024	2d sand	=14.5° B	18,700
·-Morril Oil Co., W. State and Douglas ets	11			15.0°B	40,000
x Oil Co., 41 Bryson Block	3	870			
		930			
		920		17.0°B	4,500
l, James, 1127 Temple Street	2	810		15.0°B	9,500
		745			
ond Oil Co., Third and Main Streets	7	825	700	14.5°B·	12,000
il Co., 230 S. Spring Street	3	820			
		900	765	15.0°B	7,000
son, Geo. S., 233 W. First Street	1	825	515	15.0°B	1,800
·, Burns & Mathay	2	690			
		715			5,000
rtzentahl, Mrs. L., First and Union Sts.	3	800		18.0°B	3,000
n, M. N., Second and Broadway	1	1,026	600	14.0°B	600
Chas. E., 150 S. Broadway	3	735	680	17.0°B	6,000
& Callender, Second and Broadway	1	1,100	750	15.0°B	2,000
er & Tonkin	3				3,300
ern California Oil Co., 408 S. Broadway.	2	894			
		888			1,000
ig & Co., 310 S. Edgeware Road	2	660			
		800			500
s, Mrs. A., 233 N. Grand Ave.	3	750			
		685	450		None.
		540			
; Oil Co., 41 Bryson Block	7	850		15.5°B	3,000
ı, A. H., 121 S. Broadway	3	850	825	11 0°B	
pson, R. C., Omaha Street	1	840		15.5°B	1,650
nson, Mrs. C., 1318 Omaha Street	1	830		15.5°B	2,000
, G. W., Washington Street	2	700			
		940			1,000
r Bros., 206 Patton Street	12				18,000
Oil Co., Byrne Block	7				8,152
·r, Rust & Hunt, 342 Metcalf Street	3	780		16.0°B	10,000
ıson & Kellam, 147 S. Broadway	1	780		16.0°B	1,000
R. W., 301 Welcome Street	1	840		16.0°B	3,000
	1	810	770		New.
.l					729,695

CHAPTER II.

Pipe-Lines and Tankage.

.01. *Pacific Oil Refinery and Supply Company.*—Its pipe-line ıds from the Second-Street Park oil-field to its tanks on Santa venue. The plant consists of 1 mile of 6″ pipe, 4 miles of 4″ pipe, ½ mile of 3½″ pipe. The tankage is 75,000 bbls.

.02. *Union Oil Company.* Its pipe-line extends from the Second-t Park oil-field to Palmetto Street, on the Southern California vay. The plant consists of 5 miles of 4″ pipe, principally, and a ıge capacity of 32,000 bbls.

.03. The daily yield of oil during 1895 was rather more than 2,000

bbls. During the first half of 1896, it was estimated approximately at 1,400 bbls. a day.

1.2.04. *Stock of Oil on Hand at Los Angeles.*—

In the field—March 24, 1896	37,500 bbls.
In the field—May 2, 1896	38,700 bbls.
In the field—May 15, 1896	34,100 bbls.
In the field—May 30, 1896	34,190 bbls.
Outside the field—May 30, 1896	55,800 bbls.
In the field—June 29, 1896	32,100 bbls.
In the field—July 20, 1896	29,870 bbls.

1.2.05. A canvass of the owners leads to the conclusion that during 1895 a decrease of from 25% to 50% was noted in the product of the wells at the Second-Street Park oil-field.

1.2.06. The Los Angeles wells yield only a small quantity of gas, and but few instances of its being used were noted.

1.2.07. *The Tankage in May, 1896.*—

In the Second-Street Park field	70,000 bbls.
Outside the Second-Street Park field—	
Southern California Supply Co.	70,000 bbls.
Union Oil Co.	32,000 bbls.
Puente	6,500 bbls.
Standard Oil	45,000 bbls.
Oil Exchange	3,600 bbls.
Hoffman & Weller	2,400 bbls.
Pritchard & Co.	2,400 bbls.
S. P. R. R. Co.	20,000 bbls.
Total	251,900 bbls.

CHAPTER III.

Abandoned Wells.

1.3.01. The following wells which were drilled for oil proved unsuccessful and appear to be abandoned. There are also other wells situated in the northern and southern outskirts of the Second-Street Park oil-field which proved unsuccessful and are abandoned. It is said that the trouble with most of them was water, or water and quicksand:

1.3.02. *Allison & Barlow well*, near corner of Beaudry Avenue and Second Street, is 1,000′ deep. Abandoned on account of water.

1.3.03. *Angelina Heights well* is in lot 26, block 19. The formation is principally a dark-colored shale with hard strata; sunk to a depth of 1,186′, and found quicksand with water. A stratum of oil-sand 6′ thick was struck at a depth of 960′; and is said to have yielded a green oil. Abandoned on account of water.

1.3.04. *Boyle Heights wells* were drilled several years ago; one about 300′ and the other about 600′ deep. It is said that a small amount of oil was obtained. Abandoned on account of water.

1.3.05. *Bryant & Co.'s well* is at Ivanhoe and a short distance northeast of the City of Los Angeles. It is said that this well is more than 1,000′ deep; that the formation is principally soft sandstone and sandy shale, with hard calcareous strata. Small quantities of oil and much water were struck. Abandoned on account of water.

1.3.06. *Chance well* is near the corner of Echo Park Road and Belmont Avenue; it penetrated sandy and clayey strata to 450′ in depth, when there was a showing of oil, but too much water and quicksand caused the well to be abandoned.

1.3.07. *Chandler (Brook) well* is on lot 20, block 7, corner Magnolia and Breed streets, Los Angeles. Sandy shale and clay with oil to 100′ in depth; surface water cased off at 90′ depth, thence bluish mud to 324′ depth. At 150′ a thin, hard stratum was passed through, beneath which there was a good showing of heavy oil. At 335′ large quantities of salt water were encountered. It is said that this well is abandoned on account of the water.

1.3.08. *Denker wells* are about 10 miles a little north of west of the City of Los Angeles, on the northern part of the Rancho Rodeo de las Aguas, more generally known as the Hammel & Denker ranch, and just at the foot of the Santa Monica range of mountains. On this ranch there are some tar springs and some patches of asphaltum, and several years ago A. H. Denker drilled two 520′ wells. The formation penetrated, as shown by the record of one of these wells, is, slate, shale, and sandstone, 100′; black sandstone, 100′; slate, 10′; sandstone, with a little oil, 100′; sandstone, with tar and sulphur water, 65′; very fine hard sand, 15′; sand, with a little oil, 15′; black slate, with pyrites, 25′. At 25′ depth, the first water was encountered; at 465′ depth there was strong sulphur water and some gas. Both these wells yield flowing sulphureted water and small quantities of oil.

1.3.09. *Dunkleberger well*, corner of Emerald and Second streets; is 800′ in depth, with very little oil. Abandoned on account of water.

1.3.10. *Eureka Oil Co. (Thomas) well.* This well is on the line of Effie Street, about 400′ north of Berkeley Avenue. It is said that this well is 700′ deep; that there was some showing of oil, but that the well is abandoned on account of water.

1.3.11. *Fudicker well*, 550′ deep, is south of the corner of First and Reno streets. Formation, sandstone and shale. The sandstone showed much oil and a great deal of water. Abandoned on account of water. A stream of water, accompanied by a little oil, flows from this well.

1.3.12. *Gasson well* is on the Hunter tract and west of Garvanza; 985′ deep; no oil; water.

1.3.13. *Green Meadow ranch well* is on Washington Street, and about 5½ miles west of Los Angeles. This well was drilled to about 500′ in depth. The formation is soft sandstone; much water; some gas. From this well several Quaternary or late Pliocene fossils were obtained.

1.3.14. *Hoag & Silent well* is in block 4 of East Los Angeles, and a short distance northwest of the Chandler well. It is said to be abandoned.

1.3.15. *Johnson well* is near the corner of Figueroa and Third streets; 1,100′ deep; water.

1.3.16. *La Brea Rancho well* is about 6 miles west of Los Angeles; two wells were drilled on this ranch, and the following record is given in our VIIth Report of one, a 658′ well: "At a depth of 81′, coarse gray sand; at 83′, very fine-grained black bituminous shale; at 420′, coarse-grained pebbly sand, yellowish-brown in color; at 479′, dark-colored bituminous shale; at 651′ and at 658′, black sticky bituminous shale." Of the other, a 1,485′ well: "Black sand and brea, 43′; quicksand, 45′; hard shale, 18′; black sand and brea, 248′; hard shale, 18′; sand and brea, 618′; soft blue mud, 320′; oil-sand, 30′; soft blue mud, 135′. At 1,000′ the well flowed salt water; there was much gas, but no valuable quantity of oil."

1.3.17. Between the rancho La Brea and the hills lying south of the

rancho La Cienega, a number of other wells have been sunk, ranging from 80′ to 200′ in depth. Sulphur water and gas have been found, but no valuable quantity of oil.

1.3.18. *Lookout Mountain well* is 550′ deep; small showing of oil. Abandoned on account of water; the water is said to be potable.

1.3.19. *McIntosh well*, near the corner of State and Mignonette streets, is 1,025′ deep. Formation, soft clayey sandstone; much water near the bottom of the well; salt water; no oil.

1.3.20. *McIntosh well* is near the corner of Bellevue Avenue and Old Temple road. The formation penetrated is, adobe soil, 3′; shale, with seams of sand and black earth, 80′; oil-sand, with small vein of fresh water, to 85′; shale, with strata of sand, to 165′; soft sandrock and traces of oil, to 190′; clayey shale, to 200′; casing reduced to 12¼″; clayey shale, which caved badly, to 315′; casing reduced to 10¼″; hard white stratum, to 316′; hard sandy stratum, with water, to 355′; soft bluish clayey shale (at this depth the water was cased off), to 406′; sand and oil, to 432′; casing reduced to 8″; sand and oil, to 462′; sand and shale, to 470′; shale, to 520′; sand and more oil, 530′. It is said that at this depth the oil rose to within 200′ of the top of the well, and that in one afternoon more than 20 bbls. of oil were bailed out of the well. Sand, with fresh water, to 642′; shale, 662′; sandrock, 678′; hard sandrock, 725′; shale, to 743′; sand, 900′; shale, 904′; sandstone and thin strata of shale, to 945′; sand and shale, to 1,000′; at 996′ the casing was reduced to 5⅝″; oil-sand with strata of shale, 1,004′. Abandoned on account of water.

1.3.21. *Near River Station.* Asphaltum and gas were struck in an 80′ well in the bed of the Los Angeles River, near River Station, on the S. P. R. R.

1.3.22. *Obar well* is on the south end of the Gould & Fletcher tract, near the end of the old Elysian Park car-line; is 7″ in diameter. Formation: yellow sandstone, 80′; hard sandstone, 100′; dark-colored shale and clay, alternating, to 350′. It is said that traces of oil were found; that the well was "torpedoed" at a depth of 80′, and that water rose to within 35′ of the surface.

1.3.23. *Okell & Barber well* is southeast of the corner of Bellevue Avenue and Old Temple road. The formation is: adobe soil, 30′; (water); soft sandstone, to 33′; shale, with oil, to 90′; blue shale, to 150′; (oil at 110′); hard stratum to 158′; soft sandstone, 180′; (fresh water); soft sandstone, 300′. Abandoned on account of the water.

1.3.24. *Oregon Oil Co.'s well* is on Vermont Avenue near Barrow. Formation penetrated: soil, 6′; yellow shale, to 40′; blue shale, to 100′; alternate strata of sand and shale, to 189′; hard sandstone, to 209′. It is said that a stratum of gravel with fresh water was struck at 100′ depth. This well is said to be abandoned.

1.3.25. *Perkins well* is near Jewell and Third streets; 600′ deep. Salt water.

1.3.26. *Polhemus old well* is south of Bellevue Avenue, near the Okell & Barber well, and is said to be 390′ deep. It was drilled in an early day, and yields water and a little heavy oil.

1.3.27. *Thompson Bros. well* is on Morton Street, between Geneva and Mecca avenues. The formation is: sand rock, 60′; sandy and clayey strata, to 625′; thin strata of oil-sand, much water.

1.3.28. *Sisters' Hospital wells.* On the hill east of the hospital are

two wells 800′ in depth. Abandoned on account of water, which is said to be potable.

1.3.29. *Union Oil Co.'s well*, 900′ deep, is southeast of the corner of First and Alvarado streets. An oil-yielding sand was struck within 50′ of the surface. Below that depth, soft, sandy formations were penetrated, and much water was encountered; at 520′ there was a particularly strong flow of water and gas. Abandoned on account of water.

1.3.30. *Villa Tract wells* are near Brooklyn Heights. These wells were drilled several years ago. In one a small amount of oil was struck.

1.3.31. *Wilmot & Holden well*, on Dr. Long's ranch on Prospect Avenue, about half a mile east of Vermont Avenue, is 7″ in diameter. The formation penetrated is: adobe, 12′; shale and sandstone, nearly all sandstone, 500′. It is said that fresh water was struck at 40′; flowing water and a little oil at 175′ depth. This well appears to be abandoned.

1.3.32. *The Wilshire well* is on the Wilshire tract, west of West Lake Park. Formation is soft, sandy strata, 490′ (at this depth a thin stratum of sand was penetrated, which yielded a heavy oil); soft bituminous shale to a depth of 1,000′. At 890′ in depth, salt water was struck, which rose within 500′ of the top of the well.

CHAPTER IV.

Miscellaneous Wells.

1.4.01. *Benedict Ransh.* Oil was struck in a well sunk for water on the Benedict ranch in S.E. ¼ of N.W. ¼ of Sec. 14, T. 1 S., R. 14 W., S. B. M.

1.4.02. *Hellman Ranch gas well* is a few miles southeast of Los Angeles. It yields a slightly sulphureted water, through which inflammable gas bubbles freely. This was at one time used in the ranch-house for heating and lighting.

1.4.03. *Maier & Zobelein's two wells* are 1,100′ and 1,300′ deep, respectively, and are on Commercial Street, between Garcia and Vignes streets. The formation is principally blue clay and quicksand; a little water, but no oil.

1.4.05. *Protestant Orphans' Home well*, situated in the northern part of Los Angeles, is 60′ deep. In this well gas was struck, and it is said to have burned from the top of a 7″ casing with a flame over 6′ high for more than an hour.

1.4.06. *Reynolds & Wiggin well* is on the Kercheval tract, near the corner of Santa Fe Avenue and Grant Street. Formation: gravel and sand, 500′; stiff clay and sandy clay, 330′. At a depth of 800′ a hard calcareous stratum was penetrated. From this well some fossils were obtained. (See table of fossils.) This well was not completed in July, 1896.

1.4.07. *Rosencrantz gas well*, 135′ deep, is about 11 miles south of Los Angeles. It was drilled in 1886 (?), and is said to have yielded a strong flow of gas when first drilled; in 1896 the well was nearly full of water, and yielded some gas. See our VIIth Report, p. 79.

1.4.08. *United States Hotel well* at Los Angeles was drilled in 1883. The formation penetrated is: gravel and surface soil, 40′; bluish clay shale to a depth of 900′ (inflammable gas). On the completion of the well, brackish water rose to within 20′ of the top of the well.

CHAPTER V.

The Puente Oil-Wells.

1.5.01. The hills in which the Puente oil-wells are situated appear to be an east extension of a line of elevation which can be traced in a southeasterly direction from the City of Los Angeles. These hills, as seen at the Puente oil-wells, are formed by a series of closely compressed folds in the rocky formation, which have an east and west trend. At the base of these hills soft sandstones and conglomerates are found, and in some places a white, chalk-like, diatomaceous rock, similar to that seen at Los Angeles, alternates with reddish-brown sandy strata, forming parti-colored banks, in which the strata vary from a few inches to less than an inch in thickness. A small collection of fossils was obtained from these formations, which show a preponderance of Pliocene forms.

1.5.02. The higher portions of the Puente Hills are composed of both hard and soft sandstones and shales, and these rocks are often separated by hard calcareous strata. Were it not for the latter it would be very difficult to learn much about the stratigraphy of the Puente Hills, for the soft rocks readily disintegrate and become covered with alluvium, while the hard calcareous strata resist the action of the elements and, in many places, afford the only clue to the dip of the formation. These hard calcareous rocks, and the sandstones and shales associated with them, are evidently older and are more disturbed than the soft sandstones and conglomerates previously mentioned. The only organisms noted in these hard calcareous rocks are the bones and scales of fish, and a few carbonized plant-remains. There has been so much geological disturbance in the Puente Hills that it renders the locality an unfavorable one for estimating the thickness of the formations named, and it also prevents a definite conclusion being formed as to the conformity or non-conformity of the older and the more recent strata.

1.5.03. The formations at the base of the Puente Hills contain fossiliferous strata, and a small collection of fossils was obtained therefrom in Brea Cañon. They show the following range:

Living, Quaternary	1
Living, Quaternary, Pliocene	5
Living, Quaternary, Pliocene, Miocene	11
Quaternary	1
Pliocene	1
Quaternary, Pliocene, Miocene	1
Pliocene, Miocene	4
Miocene	1

1.5.04. In that portion of the Puente Hills which is under discussion, petroleum is found at the Puente oil-wells and at Brea Cañon. (See map, Fig. 32.)

1.5.05. The Puente oil-wells, as described in our VIIth Report, are situated on Puente Gulch, and are about 5 miles distant in a southeasterly direction from Puente station, on the S. P. R. R., and about 6 miles distant in a northwesterly direction from Fullerton, on the San Diego branch of S. C. Ry. They consist of twenty-five oil-producing wells, a water-well, and a few non-productive wells. Their depth varies from 700′ to 1,750′, and the total yield is about 300 bbls. of oil a day.

Sixteen of them are situated on the north side of Puente Gulch, two in the gulch, and the remainder southeast of it. (See Fig. 3.)

1.5.06. Investigation leads to the conclusion that the Puente Gulch has been worn along the axis of a fold, for the strata immediately north of the gulch, with a few exceptions, dip in a northerly direction, while those immediately south of the gulch dip in a southerly direction.

1.5.07. At the northeast end of Puente Gulch, the scanty rock exposures indicate that the formation is crumpled into two short anticlinal folds. It is probable that these folds are represented by faults at no great distance beneath the surface, and that they coalesce in one main fold in Puente Cañon.

1.5.08. The table on page 20 shows the depth, life, and the character of the oil the Puente wells yield.

1.5.09. In 1895, the Puente Oil Co. drilled two wells, which are distant respectively about half a mile and a mile in a southeasterly direction from Puente Gulch. Although a depth of more than 1,000′ was reached, they proved practically dry holes, and were abandoned. The formation penetrated by these dry wells resembles that pierced by the oil-wells in Puente Gulch, which shows that the probabilities as to striking a remunerative deposit of petroleum depend, not only on the position of the rocks prospected in point of vertical range, but largely on the attending structural conditions. Subsequently, two wells were drilled east of the oil-wells in the Puente Gulch and in a line with the strike of the formation which previous drilling had shown to contain oil in valuable quantities. It is said that these wells are very remunerative. Some of the wells at Puente yield sufficient gas to be of local value. It is used beneath the steam-boilers and for domestic purposes. Some of the oil is effervescent with gas when it is brought to the surface.

1.5.10. The Puente Oil Co. owns two pipe-lines. One is a 2″ line and 8 miles in length; it connects the Puente oil-wells with Puente station, on the S. P. R. R. The other is a 3″ line and 15 miles in length, and connects the Puente oil-wells with the refinery belonging to the Puente Oil Co. at Chino, in San Bernardino County.

1.5.11. Nearly 2 miles in a southeasterly direction from the Puente oil-wells is Brea Cañon, where there are seepages of heavy oil. Between these two places a spur of hills extends to the southwest. On the north side of Brea Cañon a formation is exposed, which is elsewhere mentioned as being characteristic of the Pliocene formations at Los Angeles. It consists of thin strata of soft, white, chalk-like diatomaceous rock, which alternate with thin strata of reddish-brown sand. This formation dips N. 17° E. at an angle of 35°, and appears to rest somewhat nonconformably on a soft sandstone containing numerous white particles. The soft sandstone rests on conglomerate and the conglomerate on micaceous sandstone, which dips N. 25° E. at an angle of 65°. The white and red formation, the soft sandstone and the conglomerate, appear to rest nearly, but not quite, conformably on one another. On the south side of Brea Cañon are soft sandstones and conglomerates very similar to those last mentioned; but they are more or less impregnated with petroleum, and show a dip of S. 20° W. at an angle of 70°. A short distance farther south the dip is due south at an angle of about 40°. Along the south side of Brea Cañon there is a series of seepages of heavy oil which has a course of S. 78° W., and this direction conforms to that of the axis of the anticline on which the oil seepages are situated.

RECORD OF PUENTE OIL-WELLS, DECEMBER, 1894.

Number of Well	Diameter of Casing	Year when Completed	Depth	Depth at which Oil was Struck.	Depth of Principal Oil-Yielding Strata.	Daily Yield when Completed	Daily Yield in 1894.	Character of Oil.	Decrease in Yield per Annum	Depth where Water was Cased Off	Remarks.
	Inches.		Feet.	Feet.	Feet.	Bbls.	Bbls.		Per Ct.	Feet.	
1	5½		50	Near surface.			0.5	Heavy, black.			
2	5½		250	Near surface.			0.5	Heavy, black.			
3	8 to 5½		300	Near surface.			0.7	Heavy oil.			
4	12 to 5	1885	970	150	350	10	5	Heavy oil.	5		
5	12 to 5¼	1886	1,202	350	430	25	6	30° B.	9		Much gas.
6	12 to 4⅞	1887	750	285	650	25	6	30° B.	10		Much gas.
7	14 to 5¼	1887	867	595	595 to bottom of well.	35	3	30° B.	13		Much gas.
10	14 to 7¼	1888		540			1.5	Heavy oil.			
15	14 to 6⅝	1890	875	575	630	35	25	30° B.	7		Much gas.
13	14 to 4⅛	1889	1,075	700	700	15	5	30° B.	7		Some gas.
16	14 to 4 3/16	1891	985	700	700	35	8	30° B.	28		Some gas.
12	14 to 5⅛	1888	1,060	685	965	35	5	25° B.	5		Little gas.
8	11¼ to 5	1887–8	925	400	400	19	4	30° B.	13	400	Some gas.
9	12¾ to 4	1888–9	960	425	425	19	6	30° B.	13	329	Some gas.
19	14 to 6¾		710	365	365	19	5	30° B.			
14	14 to 4⅛	1889	1,140	620	620	10	4	Heavy oil.	12		
18	14 to 5⅞	1892	710	150	600	18	5	30° B.	36	362	Little gas.
11	14 to 3 3/16	1888	1,401	270	700	12	4.5	25° B.	10		Not much gas down 1,300′.
20	14 to 6	1892	800	500	500	20	2	30° B.	20	424	Gas.
23	12⅝ to 3½	1892	1,213	470	890	60	15	35° B.	37	320	Gas.
21	12⅝ to 5⅞	1892	800	325	640	12	6	35° B.	25	270	Gas.
22	12⅝ to 5	1892	1,125	455	700	150	65	35° B.	29	300	Much gas.
27	14 to 5⅞	1894	1,155	480	480	125	60	35° B.	52		Much gas.
26	14 to 5⅞	1893	1,320	480	700	125	25	35° B.	80		
24		1893	1,420	Heavy oil, not sufficient to pay for pumping.							
25	12⅝ to 4 3/16	1893	1,225	790	790	8	3	Heavy oil.	62		

1.5.12. The brea, or impure asphaltum and oil-soaked earth, which is exposed on Brea Cañon, is sometimes mined for fuel. At one point an excavation has been made, and a tunnel run a short distance in the brea. The excavation is filled with water, and heavy oil floating on it.

1.5.13. Several years ago two or three wells (the Chandler wells) were sunk, about 4 miles southeast of the Puente oil-wells. They penetrate a formation similar to that seen in Brea Cañon, and are said to be 200′ or 300′ deep. In December, 1894, they appeared to be abandoned. It is said that they yielded 2 or 3 bbls. of heavy oil a day by pumping. Around the wells are seepages of heavy oil and deposits of brea. This brea can be traced from the Chandler wells for a distance of nearly 2 miles to the most western oil seepages in Brea Cañon.

1.5.14. No one who has compared the geological formation in Brea Cañon and the geological formation in the western portion of Los Angeles can fail to notice their great resemblance in lithological character; but the collection of fossils from Brea Cañon indicates a somewhat greater age than does the collection made at Los Angeles. One Miocene fossil was obtained from oil-soaked strata near the axis of the fold on which the oil seepages in Brea Cañon are situated.

CHAPTER VI.

The districts in which the following oil-wells are situated have not yet been visited:

1.6.01. *Bluett & Mullen wells.* Their oil claims comprise about 3,000 acres, and are in the Palomares mining district, about 4 miles north of Castac. One well was 400′ deep and incomplete in May, 1896.

1.6.02. *Central Oil Co.'s wells.* This Los Angeles company has leased 3,000 acres of land about 1 mile north of Whittier. In April, 1896, one well had been drilled to 700′ in depth, penetrating at a depth of 520′ a stratum of oil-sand.

1.6.03. *Pico oil-wells.* These are situated in what is commonly known as the Pico Cañon oil-field, which is about 7 miles from Newhall. There are about thirty-five wells in Pico Cañon, one in Elsmere Cañon, and one in Wylie Cañon. These wells vary from 650′ to 1,700′ in depth. (See our Xth Report, p. 283.) The output of these wells during 1895 was about 150,000 bbls.

1.6.04. *Union Oil Co.* has leased, and is prospecting territory west of the Puente oil-wells. It is said that it has struck oil-sand in a well drilled there.

1.6.05. *Petroleum Statistics of Los Angeles County for the year 1895:*

	Bbls.	Value.
Los Angeles oil-wells yielded	729,695	$437,817
Puente oil-wells yielded	100,000	100,000
Pico oil-wells yielded	150,000	195,000
Total	979,695	$732,817

PART II.

VENTURA COUNTY.

CHAPTER I.

Geology, Districts, Wells, Etc.

2.1.01. The best opportunity of studying the geology of the petroleum-yielding formations on the north side of Santa Clara River is found in the Sespe oil district and vicinity. The territory commonly known as

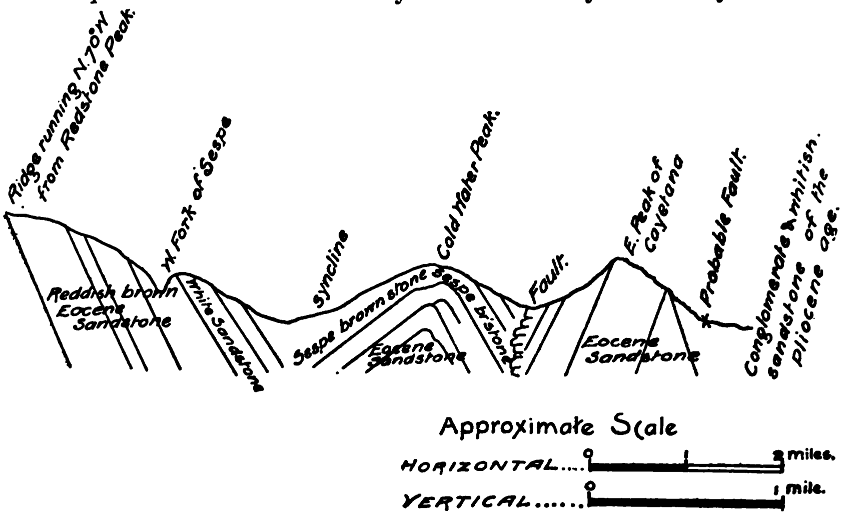

FIG. 8. CROSS-SECTION THROUGH DEVIL'S GATE MINING DISTRICT.

the Sespe district is in the range of mountains which borders the valley of Santa Clara River on the north. This territory comprises the Little Sespe and the Devil's Gate oil-mining districts. It includes the drainage basins of the Little Sespe, Pine, Cold Water, Tar, Stony Corral, and Alder creeks. These streams are tributaries of Sespe River, which flows through the center of the territory referred to. The Sespe and its tributaries are torrential during the rainy season, and their channels have a grade of 150′ to more than 600′ to the mile. They run through deep cañons, and their channels are strewn with huge masses of water-worn rock. The rocks exposed in the Sespe district are principally hard sandstones and dark-colored shales of the Eocene period, which have been denuded of more recent Tertiary formations; the latter form a ridge, which traverses the eastern side of the Sespe district; they also consti-

Fig. 6. Mt. Cayetana and Santa Paula Cañon, from Hills South of Sulphur Mountains

Fig. 7 Santa Clara Valley, Sulphur Mountains, and Silverthread Oil District, from S.W. Slope of Mt. Cayetana.

tute a great portion of the foothills which lie between the Sespe district and the valley of Santa Clara River.

2.1.02. The ridge referred to forms a divide between the Sespe and its tributaries on the west, and Pole Cañon, Hopper, and Piru creeks on the east.

2.1.03. The rocks of the Sespe district constitute portions of two anticlinal folds. (See Fig. 8.) One of these folds traverses the northern part of this territory.

In the Sespe district the most elevated portion of this fold is locally known as Redstone Peak. Its axis can be traced with a course of about N. 50° W. from station A (see map, Fig. 33), on the ridge which, as before mentioned, traverses the eastern side of the Sespe district, through the group of oil-wells at Tar Creek, along the northern slope of Redstone Peak, across Sespe Creek, and thence to some point north of Mount Topo Topa. For convenience this fold is referred to as the Redstone Peak anticline. It is an unsymmetrical fold, and in the Sespe district the dip of the rocks forming it has a tendency to swing around its axis. On the northern slope of this fold the dip varies from N. 45° E. to N. 70° E., and on the south slope, from S. 45° E. to S. 70° E. As this fold extends westward it appears to be much more symmetrical than it is in the Sespe district.

2.1.04. The other fold is also very unsymmetrical, its southern slope being much steeper than its northern. It has a course of about S. 85° W., and can be traced from station B (see map, Fig. 33), about half a mile east of the well of the California Oil Co., to the mountains at the east end of Ojai Valley; at its eastern extremity the dip of the Eocene rocks forming this fold swing around the axis of the fold, and it ranges from S. 10° E. to N. 70° E. The axis of this fold is well exposed at the head of Cold Water Cañon. For convenience this fold is referred to as the Cold Water anticline. (See Fig. 25.)

2.1.05. Farther eastward the more recent Tertiary strata seem to belong to the southern slope of the Redstone Peak anticline, although on the summit of Four Forks Peak and on the south fork of Tar Creek there are some rocks which dip to the east. In the syncline between the two folds, and in some places on the northern slope of the Redstone Peak fold, the angle of the dip is abnormally low. It is evident that the Cold Water anticline dies out in the Sespe district, and it is probable that the Redstone Peak anticline dies out at some point not very much farther to the eastward.

2.1.06. An idea of the structure of the western portion of the Sespe district can be obtained by referring to Fig. 8, showing cross-section from station C on the east peak of Mount Cayetana through Cold Water Peak to a point on the ridge which runs N. 70° W. from Redstone Peak.

2.1.07. The relative geological position of the rocks penetrated by the oil-wells in the Sespe district, and the rocks penetrated by the oil-wells at Sulphur Mountains and in Sisar Valley, cannot be understood without mastering the structure of Mount Cayetana, a mass of Eocene sandstone which rises between Sespe and Santa Paula cañons. (See Figs. 6 and 25.) On the northern side of Cayetana a strike fault extends from Sespe Cañon to the head of Ojai Valley. It passes a short distance south of the axis of the Cold Water Cañon anticline. In many places its course is marked by a trough which has a course nearly coinciding with the strike of the formation. This fault

can be observed in Santa Paula Creek, a short distance north of the point marked "Alexander's," in Sec. 10, T. 5 N., R. 21 W., S. B. M.; the upthrow is to the south; and at the head of Pine Creek the Sespe brownstone has been brought into contact with the buff-colored Eocene sandstone. The east fork of Santa Paula Creek has cut its way partly through the rocks which have been shattered by this fault and partly along the axis of the Cold Water anticline. On the northern bank of this stream, the whitish sandstone underlying the Sespe brownstone is exposed.

2.1.08. East of Sespe Creek this fault splits and forms a fault which extends eastward and passes a short distance south of the well of the California Oil Co. and a fault which crosses the Sespe River a short distance above the mouth of Little Sespe Creek.

2.1.09. A reconnaissance southward of Mount Cayetana leads to the conclusion that a fault traverses the southern base of that mountain with a course which is nearly coincident with the strike of the formation. This fault is marked by a line of springs, a few seepages of oil, and, in some places, by the crushed and broken nature of the rocks. The upthrow appears to be to the north, for the hard, buff-colored Eocene sandstones of Mount Cayetana are nearly in contact with formations in the foothills which contain Miocene and Pliocene fossils. West of Santa Paula Creek this fault splits, one fault passes up Sisar Valley, one along the southern flank of the Sulphur Mountains, and probably a third extends through the center of the eastern end of Sulphur Mountains.

2.1.10. A reconnaissance northward of the Sespe district and toward the head of Agua Blanca Creek showed a fold still north of the one noted at Redstone Peak. The formations composing this most northern fold resemble those seen in the Sespe district, and rocks physically resembling the hard Eocene sandstones are in contact with the granite rocks of the Alamo Mountains. These sandstones appear to be more crushed and metamorphosed than they are in the Sespe district.

2.1.11. From the foregoing it is apparent that the geological structure of the territory under discussion presents a series of closely compressed anticlinal folds. These folds are modified by faults, the most important of which have a course which is nearly coincident with the strike of the formations they traverse. The most numerous faults, especially in the hardest rocks, are dip-faults; but they are usually of minor importance. It is probable, however, that the course of some of the principal cañons has been determined by dip-faults. In a few places lateral thrusts locally complicate the stratigraphy. Rightly to differentiate the rocks of this, or any other territory, it is necessary to trace the folds and the principal faults. It is not easy to do this in every instance. The chief obstacles are the alluvium in the foothills, and the dense brush and rocky debris in the higher elevations. Fig. 8 shows the mountain structure along a line extending northward from the eastern peak of Mount Cayetana, through the Devil's Gate oil-mining district, to the ridge which runs N. 70° W. from Redstone Peak. It shows the eastern peak of Mount Cayetana, the Cold Water anticline, and the southern slope of Redstone Peak.

FIG. 9. SLATY SHALE, SULPHUR MOUNTAINS.

FIG. 10. DARK-COLORED SHALE, TAR CREEK, SESPE DISTRICT.

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SESPE DISTRICT.

2.1.12. The most recent Tertiary formation in the Sespe district consists of sandstone strata, whitish to yellowish in color, usually rather fine-grained, and the exposed surfaces vary from soft and friable to moderately hard. These sandstones resemble those which are situated and extend north from the head of Pole Creek Cañon. Their physical character corresponds to that of the whitish sandstone exposed at the base of Mount Cayetana and to certain sandstones on Ventura River, as hereinafter noted. At the last two places named they contain Miocene and Pliocene fossils.

2.1.13. As before mentioned, these sandstones and certain shales on which they rest form a ridge of mountains on the eastern side of the Sespe district. This formation terminates abruptly at the point marked "North end of white sandstone ridge." A good place for inspecting this sandstone is below Oak Tree Point. There it rests apparently conformably on bleached calcareo-silicious shale, much of which exhibits a slaty cleavage like that seen at the Sulphur Mountains (Fig. 9) as hereafter described. This conformity can also be observed in Pole Creek Cañon, but at that place the slaty shale is very silicious. These bleached slaty shales rest apparently conformably on strata of grayish sandstone which are of no great thickness, and which rest conformably on dark-colored shales. The latter are traversed by thin strata of hard bituminous limestone and by strata consisting of nodular masses of limestone. (See Fig. 10.) The upper portion of this shale exhibits a slaty cleavage, and bleaches on exposure. In some places there are spots where this shale has been bleached apparently by the action of gas. The lower portion of this dark-colored shale is somewhat sandy, and the limestone strata which traverse it are fossiliferous. Although these fossils are rather poorly preserved, a small collection of them was made. (See table of fossils.)

2.1.14. Reference to this table shows that the vertical range of the fossils obtained from this formation at Tar Creek and on the divide between Tar and Maple creeks is:

Eocene (heretofore classed as Cretaceous B), Tejon	9
Miocene	4
Living, Quaternary, Pliocene, Miocene	2
Living, Quaternary, Pliocene	3
Undetermined	2

It is obvious that these dark-colored shales must be regarded as transition beds between the Miocene and Eocene formations.

2.1.15. The physical characteristics of these dark-colored shales and of the slaty shales overlying them resemble those of the dark-colored shales and bleached slaty shales on the Sulphur Mountains, and of the dark-colored shales exposed at points where the foothills are cut through by the Sespe River and Pole Creek Cañon. These shales rest apparently conformably on drab sandstone, which is of no great thickness.

2.1.16. The lowermost portions of these dark-colored shales, and probably the drab sandstones underlying them, constitute the uppermost oil-yielding formations in the Sespe district. (See Fig. 11.) The drab sandstone rests apparently conformably on the Sespe brownstone formation; at least no marked non-conformity was observed. The Sespe brownstone formation consists of sandstone shales and conglomerate—all being

more or less brown in color. The Sespe brownstone is a sandstone which is valuable as structural material. (See Fig. 14.) It is somewhat extensively quarried by Messrs. Henly and the Mentone Brownstone Company. In the Sespe district, a wide outcrop of this sandstone has been exposed by denudation, the greatest mass being in the syncline between Redstone Peak and the Cold Water anticline. This is the case especially on the western bank of Sespe Creek, where huge ledges of good building-stone are exposed, and there are many loose slabs which exceed 30′x 30′x 10′ in dimension. (See Fig. 14.) The best building-stone appears to constitute the upper portion of this brown-sandstone formation, and there are said to be several ledges of it which aggregate about 200′ in thickness. Although this stone is generally known as the Sespe brownstone, and

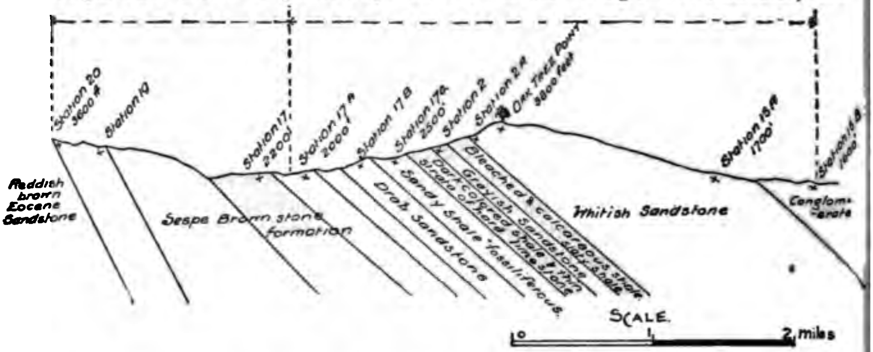


FIG. 13. CROSS-SECTION, REDSTONE PEAK TO AGUA BLANCA CREEK, SESPE DISTRICT.

much of it is of a dark-brown color; more correctly speaking, it varies from reddish brown to brownish or bluish black.

2.1.17. The breadth of outcrop of this brownstone formation is 2 miles. It rests apparently conformably on a hard white silicious sandstone, which is composed mainly of white quartz granules and forms a striking contrast with the brownstone as seen on the southern slope of Redstone Peak. On the summit of Redstone Peak numerous specimens of *Ostrea idriaensis* were obtained. The brown and the white sandstone are also exposed at Stone Corral Creek and the north fork of Sespe River.

2.1.18. This white sandstone rests apparently conformably on a hard buff-colored sandstone, which usually shows a calcareous reaction and contains numerous Eocene (heretofore classified as Cretaceous B) fossils. (See table of fossils.) Also, numerous peculiar cylindrical forms, which are believed by Dr. J. G. Cooper to have been sponges. This hard sandstone forms the main portion of Mount Cayetana; it is exposed at many places along the Cold Water anticline, and for the most part it constitutes the walls of Sespe Cañon. Several springs of petroleum and mineral water flow from it.

2.1.19. On the Redstone Peak anticline, where its axis is cut through by the north fork of Sespe River, there are springs of warm mineral water, which also yield a little oil, and at several other places petroleum exudes from faults and fissures in this hard Eocene sandstone.

2.1.20. On the Cold Water anticline there are oil-springs in the hard Eocene sandstone at the following places: At the well of the California Oil Co.; in two cañons between the well of the California Oil Co. and

FIG. 11. OIL-WELLS ON TAR CREEK, SESPE DISTRICT.

FIG. 12. SEEPAGES OF HEAVY OIL FROM EOCENE SANDSTONE, NORTH OF THE SILVERTHREAD WELLS.

the Sespe River; at Tar Hole, a short distance above the Devil's Gate, on the Sespe River; in Echo Cañon, west of Santa Paula Creek and north of the Silverthread oil-wells. (See Fig. 12.)

2.1.21. A reconnaissance to Agua Blanca Creek showed that the whitish sandstone mentioned first, in speaking of the Sespe formations, is overlaid by conglomerate which rests conformably upon the sandstone. By far the best sequence of rock exposure in the Sespe district can be observed along a line running eastward from Redstone Peak toward Piru and Agua Blanca creeks. Observation along the line indicated warrants the conclusion that all the formations there exposed rest practically conformably on one another; at least no marked unconformability was observed. This apparent conformability is somewhat remarkable, because in other places in California Miocene formations have been observed resting non-conformably on the Eocene rocks. The relative positions of the geological formations in the Sespe district and their approximate thickness can be noted on Fig. 13, showing a cross-section between Station 20, northwest of Redstone Peak and Station 15 B, on Agua Blanca Creek. It is quite probable that the thickness of strata is augmented by faults, but no faults of importance were observed. The angle of the dip, as shown in Fig. 13, is a somewhat arbitrary one, but it is probably not very far from a general average of the different angles at which the rocks dip between the points named. In many places the Sespe brownstone formation dips at an angle of very much less than 30°.

LITTLE SESPE DISTRICT.

2.1.22. The Little Sespe petroleum mining district was organized April 27, 1878. Its metes and bounds, as given by the Recorder of the district, are as follows: "Beginning at the large sycamore tree situated about 100 yds. south of J. Aker's house and on the line dividing his ranch from that of Mower's; thence west along the Sespe grant line 2 miles; thence north 10 miles; thence east to west line of Camulos district; thence south to Sespe grant line; thence west along the Sespe grant line to place of beginning."

2.1.23. The following groups of wells are situated in the Little Sespe mining district: The Tar Creek, the Four Forks, the Brownstone, the Kentuck, and also the oil-well belonging to the California Oil Co.

2.1.24. *At Tar Creek* thirty-one wells have been sunk, which vary from 700′ to 1,000′ in depth. For many years this group of wells has been very productive, and in 1892 they yielded at the rate of 1,500 bbls. a month. In 1895 only five of them were being pumped, and it is said that they yielded about 1,000 bbls. a month. These wells are situated near the axis and on the northern slope of the Redstone Peak anticline. They penetrate the dark-colored shales, and some of them probably pierce the drab sandstone overlying the Sespe brownstone.

2.1.25. *At Four Forks* five wells were being pumped in 1895, which were said to yield, all told, about 40 bbls. of oil a day. These wells vary from 700′ to 1,100′ in depth. It is said that the Four Forks wells have been very productive, and for a long time yielded at the rate of 750 bbls. of oil a day. Two wells drilled at Four Forks in 1895–96 by the Union Oil Co. of Santa Paula are said to be very remunerative. The Four Forks wells are situated east of the point to which the end of the

Cold Water anticline can be traced. They may be regarded as penetrating rocks forming a part of the southern slope of the Redstone Peak anticline. The formations they pierce are similar to those pierced by the wells at Tar Creek.

2.1.26. *The Brownstone* (Los Angeles) group of wells is situated at the forks of the Little Sespe, and penetrate strata which may be most appropriately referred to the southern slope of the Cold Water anticline, although that fold cannot be traced east of the forks of Little Sespe Creek. At this point there are eight wells, which are said to vary from 400′ to 800′ in depth. Three of these wells are west and five of them east of the forks of the Little Sespe. The three wells first mentioned penetrate the upper portion of the brownstone formation, and are said to be dry-holes. The five wells situated south and east of the forks of Little Sespe Creek penetrate the lower portion of the dark-colored shale formation. It is said that these wells have proved very productive, and that in 1895 they yielded, all told, at the rate of about 900 bbls. a month.

2.1.27. There is another well about a third of a mile south of the forks of the Little Sespe, and obviously lower on the southern slope of the Cold Water anticline than are the Brownstone group of wells. In this well only salt water was obtained.

2.1.28. *The Kentuck wells* are situated on the southern slope of the Cold Water anticline and about half a mile from its axis. They are on the eastern bank of Sespe River, close to the point where, as previously mentioned, an extensive fault crosses the Sespe. All these wells, except one, penetrate the dark-colored shales and the sandstone immediately underlying it. The exception referred to is No. 1: It penetrates formations which are much disturbed, and is said to be a very small producer. No. 2 was sunk in 1889, and the formation penetrated is principally dark-colored shale and light-colored sand. It was first sunk to a depth of 300′, and yielded 300 bbls. of oil daily for one week, then 200 bbls. of oil daily for two weeks. Subsequently the yield declined, and the well was sunk to 730′ in depth. When that depth was reached oil spouted over the "walking beam," and the well yielded 500 bbls. of oil daily for two months. The yield then gradually declined, and at the end of one year the well produced 60 bbls. of oil daily. In 1895 this well yielded 20 bbls. of oil daily.

2.1.29. Nos. 3, 4, 5, and 6 were drilled in the years 1890–91, and are about 700′ deep. At first they each yielded about 300 bbls. of oil a day, but in 1895 the yield of each had decreased to 20 bbls. of oil a day. No. 7 is about 730′ deep. At first it yielded 700 bbls. of oil a day, but in 1895 the yield had decreased to 50 bbls. of oil a day. Of No. 8 no record was obtained. In 1895 the total yield of the Kentuck wells was about 4,000 bbls. of oil a month. The oil has a gravity of about 26° B. when it is first taken from the wells. Many of the wells in the Sespe district yield considerable gas, which is used under the steam-boilers and for domestic purposes.

2.1.30. The well of the California Oil Co. is situated at the axis of the Cold Water anticline, or a very short distance north of it. The rocks it penetrates are brown sandstone and the hard sandstones immediately underlying it. This well was drilled in 1891, and the formation penetrated is as follows:

Hard, brown sandstone	30′
Soft, red sandstone	10′
Hard, brown sandstone	25′
Black shale	25′
Hard sandstone	20′
Soft, red, dry, clayey matter	20′
Hard, red sandstone	35′
Shale, with very heavy oil	15′
Hard, red sandstone	35′
Soft, drab-colored shale, with heavy oil	30′
Soft shale, with hard strata, the latter varying in thickness from 6″ to 8′	260′
Yellow sandstone	50′
Dark-colored shale, with oil	40′
Yellow sandstone	50′
Sand, with oil	25′
Dark-colored shale	30′
Hard, yellow sandstone	5′
Oil-sand, interstratified with hard, yellow sandstone, with oil	30′
Soft shale, with oil	10′
Hard, red sandstone	40′
Soft shale, with oil	5′
Hard, yellow, sandy shale	20′
	805′

2.1.31. Concerning this well, Mr. M. Bradfield, the superintendent, ates as follows: When a depth of 805′ was reached, the well spouted l over the top of the derrick. It filled a 250-bbl. tank in less than alf an hour. For about one month the well spouted oil twice a day, amely, at the hours of 10 A. M. and 8 P. M. At the end of that time ie well ceased to flow, but 160 bbls. of oil were pumped out of it every venty-four hours for nearly one year. The well then became choked ith sand, and the flow gradually decreased. In 1894 this well was eaned out, and it is said to have yielded 100 bbls. of oil a day. In 395 this well again became choked with sand, and as the price of oil as very low the sand was not removed. In 1896 this well was again eaned out and work was resumed to deepen it.

THE DEVIL'S GATE OIL AND BROWNSTONE MINING DISTRICT.

2.1.32. The metes and bounds of this district are as follows: "Begining at center stake of the south line of Sec. 1, T. 4 N., R. 20 W., S. B. M., id continuing west 6 miles; thence north 8 miles; thence east 6 iles; thence south 8 miles, crossing the Big Sespe River to place of ginning, being partly in townships 4 and 5 of the aforesaid meridian." he Devil's Gate mining district includes nearly the whole of that portion the Sespe River which flows through what is commonly known as the spe district, and numerous oil and brownstone claims have been located it. The portion of this district traversed during our reconnaissance composed of the following rocks, in the order of their upward vertical nge, and were hereinbefore described:

(*a*) Very hard buff and brown sandstones and dark-colored shales, ntaining Eocene fossils;

(*b*) Whitish sandstones;

(*c*) Sespe brownstone formation.

OIL DISTRICTS NORTHWEST OF SANTA PAULA.

2.1.33. The petroleum industry in the oil districts west of Santa Paula represented by the oil-wells in the Silverthread (Sisar) and Sulphur ountains districts and the O'Hara wells (see Figs. 6 and 7 and sketch

map Fig. 33); also, several tunnels which have been run for oil, as hereinafter noted. The wells and tunnels are situated in hills which culminate in the mountain ridge of San Cayetana. The principal range of hills which extends as an offshoot from Mount Cayetana is known as the Ojai range, or Sulphur Mountains. Santa Paula Creek has cut through the mountain ridge of San Cayetana and through the eastern end of the Sulphur Mountains, whence it flows southerly and joins the Santa Clara River near the town of Santa Paula. (See Figs. 6 and 7.)

2.1.34. As previously mentioned, and as can be seen by inspecting the sketch map (Fig. 33), the fold spoken of as the Cold Water anticline can be traced from the Sespe district to the mountains at the southern end of Ojai Valley.

2.1.35. South of the Cold Water anticline and west of Santa Paula Creek the Eocene formations of Mount Cayetana show two distinct folds or flexures, and their axes extend in an east and west direction. The Silverthread oil-wells are situated near the axis of the southernmost of these folds, and, as hereinafter noted, it is probable that a fault extends along the axis of this fold.

2.1.36. Farther southward more recent Tertiary formations prevail; they constitute a fold, the axis of which very nearly coincides with the course of Sisar Cañon, and about a mile to the south is another fold, the axis of which lies south of, and was nearly parallel with, the southern base of the Sulphur Mountains. All the oil-wells at the southern base of the Sulphur Mountains are situated a short distance north of the axis of this fold, except the wells in Aliso Cañon and perhaps some in Wheeler Cañon.

2.1.37. The Jones (O'Hara) well, east of Santa Paula Creek, penetrates rocks which correspond to the formation on the northern slope of this fold. It will be noted that the eastern end of the Sulphur Mountains exhibits a syncline. The rocks on the northern side of the mountains dip southerly, and form the southern slope of the fold which has its axis in Sisar Cañon. The rocks on the south side of the Sulphur Mountains dip northerly and form the northern slope of the fold which extends south of, and nearly parallel with, the southern base of the mountains.

2.1.38. The geological structure of this territory is that of closely compressed anticlinal folds. (See Fig. 34.) Along the anticlinal and synclinal axes the rocks are crushed and their stratigraphy is irregular. In a general way, the trend of the valleys, extending east and west from Santa Paula Cañon, coincides with that of the axes of the rocky folds. Along the axes of the folds, and along what appear to be lines of faulting, there are numerous springs of sulphureted water, gas, and oil. In Sisar Valley some of the mineral springs have been improved and a bath-house and camping resort have been established for the accommodation of visitors. Much of the gas is sulphureted hydrogen. It is the acid resulting from the oxidation of this gas which is the most prominent factor in the solfataric action noticeable on the southern slope of Sulphur Mountains and elsewhere, and probably many of the bleached rocks in this locality owe their whiteness to this reagent.

2.1.39. By referring to the sketch map, Fig. 33, the reader can note the relative position of the oil-wells and of the several tunnels which have been run for oil in the above described territory. The strike of the formation varies from N. 70° E. to S. 70° E., the prevailing strike being

N. 80° E., or thereabouts. As shown by the exposed rocks, the angle of the dip of the different strata varies from 40° to more than 80°. In such closely compressed folds as those herein referred to, it is reasonable to suppose that, beneath the surface, the strata in many places dip at a much greater angle than the exposed rocks indicate; nor could rocky strata be so crushed together, as they are in this locality, without the formation of numerous faults. Fig. 34 shows the relative position of the strata exposed between a line drawn S. 80° W. and N. 80° E., through the Mupu school-house, in Santa Paula Cañon, and a line drawn S. 80° W. and N. 80° E., through station D on the fold which can be traced westward from the head of Cold Water Cañon in the Sespe oil district to the mountains northeast of Ojai Valley.

2.1.40. In order to convey an idea as to the structure of the geological formations, since the angle of the dip is very irregular, the strata are represented as dipping at an angle of 65°. In order that this diagram may not be too complicated, numerous faults and the crumpled rocks which can be seen in the axis of the syncline on the Sulphur Mountains and elsewhere, are not shown. The oldest rocks (marked W in Fig. 34) are the Eocene formations, and which are exposed between Echo Cañon and the Silverthread oil district. They consist of hard reddish-brown sandstone, dark-colored shales, and whitish sandstone. These contain distinctively Eocene fossils. (See table of fossils.)

2.1.41. The formation marked X in Fig. 34 consists of soft sandstones (bituminous in places), dark-colored clays and shales. From the clays was obtained a small collection of fossils which are mostly Eocene, together with some unclassified species, said by Dr. Cooper to resemble Miocene forms. (See table of fossils.) This formation underlies the bleached slaty shales on the Sulphur Mountains, and for the most part constitutes the short, crumpled fold between Silverthread oil-wells and the northern slope of the Sulphur Mountains. These rocks are penetrated by the oil-wells of the Sulphur Mountains, the O'Hara wells, and probably by some of those of the Silverthread group. In physical appearance these dark-colored shales resemble the dark-colored shales at Tar Creek and Four Forks in the Sespe district. The fossils obtained from these shales indicate the Oligocene period.

2.1.42. The formation marked Y in Fig. 34 constitutes the upper portion of the dark-colored shale formations, which becomes slaty and passes into bleached slaty shale (Fig. 9); this shale is traversed by numerous hard calcareo-silicious strata. It is probable that this bleaching does not extend a great way beneath the surface. On the surface these bleached shales frequently appear as a white silicious rock, which adheres readily to the tongue. These shales mainly constitute the upper portion of the eastern end of the Sulphur Mountains; on the west side of the upper end of Ojai Valley they have a wide outcrop, and springs of heavy oil flow from them. Farther eastward, in Sisar Valley, the outcrop narrows, tapering and disappearing in the Silverthread oil district.

2.1.43. As previously mentioned, the upper portion of the eastern end of the Sulphur Mountains consists mainly of bleached slaty shales, similar to those which are seen in Ojai Valley, and which pinch out in the Silverthread oil district. On the northern side of the Sulphur Mountains, they can be seen at many points dipping in a southerly direction, and on the south side of the mountains they dip northerly, the synclinal axis being near the apex of that portion of the mountains

referred to. On the southern slope of the Sulphur Mountains, as observed immediately north of the Scott & Gillmore oil-wells, and as shown in Fig. 15, these slaty shales are bounded on the south by a line of decomposed and bleached shale, which at many points shows evidence of solfataric action. These bleached shales make a line along the southern flank of the Sulphur Mountains, as shown in Fig. 15. This line, or sulphur streak, as it is called, can be traced for many miles, its course being approximately S. 80° W. Along this sulphur streak or streaks (for it looks as though there were two or three running parallel), the rocks are bleached, and here and there they manifest solfataric action, resulting in the formation of small quantities of alum, sulphur, and gypsum. In some places, even at 3′ depth, the heat is too great to be borne by the bare hand. When the solfataric action ceases in one spot, it begins in another, somewhere along the line indicated. The extinct solfataras usually show a white slaty shale or whitened rotten rock; in one instance previous solfataric action has left behind a black pulverulent rock. In some places near this sulphur streak the rocks appear to have been softened and run together by heat, and the slope of the mountain is partially covered with breccia formed of angular fragments of shale and other sedimentary rock cemented with scoriaceous material. In one place, the cementing material appears to be silicious clay. The breccia is rudely stratified; its dip corresponds to the slope of the mountain south of it. This is an opposite direction to the dip of the underlying rocks, and conveys the idea that these disconnected masses of breccia are not in place. This solfataric line can be followed in an easterly direction to Santa Paula Creek, the direction being N. 80° E., or thereabouts. East of Santa Paula Creek, although the alluvium is very deep, bleached shales can be observed here and there along the course indicated, nearly to the head of Bear Cañon.

2.1.44. On the southwestern flank of Mount Cayetana, at about 1,500′ altitude above the bed of Santa Paula Creek, and a short distance northeast of the head of Bear Cañon, there is an exposure of whitish clay or bleached clay-shale intercalated with streaks of pulverulent silica, the latter being probably referable to solfataric action. There is but little doubt that the solfataric line before mentioned marks a fissure or fault running in the direction of the strike of the formation. Below the solfataric line there is a fringe of oil-seepages, from which heavy oil and maltha creep slowly down the slope of the mountain. In most places the bleached slaty shales rest on slaty shales which are not bleached. These slaty shales have been prospected by both wells and tunnels, some of which are productive. In every instance, however, the productive wells and tunnels are situated at or near the contact of the slaty shales and underlying strata. One well, drilled at or near the axis of the Sulphur Mountains syncline, is said to be 2,180′ deep and to have yielded nothing but sulphur water and a very small quantity of oil.

2.1.45. Beneath the slaty shales on the northern slope of Sulphur Mountains there is a very meager exposure of dark-colored clay shales. Indeed, at the junction of Sisar and Santa Paula creeks, the slaty shales dipping south are in immediate contact with clayey shales and sandy strata dipping north. The presence of crushed rocks, and springs of gas, oil, and sulphur water, indicate a fault, the course of which roughly corresponds to the direction of Sisar Valley and also to the anticlinal axis which is coincident with it.

Fig. 14. Brownstone in Sespe Cañon, Devil's Gate Mining District.

Fig. 15. Southern Slope of Sulphur Mountains, from Adam's Cañon.

2.1.46. On the southern side of the Sulphur Mountains, the strata underlying the slaty shales consist of dark-colored shales, sandy shales, and soft sandstones. These rocks are penetrated by all of the productive wells on the southern side of the Sulphur Mountains. These wells, as before mentioned, are situated a short distance north of the axis of the fold they penetrate.

2.1.47. The tunnels which have been run for oil show that the slaty shales which are bleached on the surface are dark-colored at no great distance beneath the ground, and that they gradually pass into the dark-colored clay shales which underlie them. The latter exhibit no slaty structure and in some places contain fossils. A small collection of these fossils of Miocene and a few Eocene forms was obtained from strata of dark-colored clay shale in the Farrell and the Magie tunnels. (See table of fossils.)

2.1.48. The rocky formations between the Sulphur Mountains and the Mupu school-house, as exposed along Santa Paula Creek, consist for the most part of sandy and clayey strata which are rather thin-bedded and exhibit a rapid transition from strata of soft sandstone to strata of clay and sandy shale. There is a limited outcrop of a similar formation in Sisar Valley. At one place this series includes a stratum of oil-yielding sand which has been cut through by Santa Paula Creek. This formation is marked Z in Fig. 34. A few fossils were obtained therefrom which are classed by Dr. J. G. Cooper as of Miocene age. At the Jones (O'Hara) oil-wells, on the southwestern slope of Mount Cayetana, the rocky formations resemble those on the southern slope of the Sulphur Mountains; farther east, near Timber Cañon, Corey Cañon, and Lord's Cañon, similar formations are found almost in contact with the hard Eocene sandstones of Mount Cayetana. The foothills immediately south of Mount Cayetana consist of soft sandstones, shales, and conglomerates, containing Miocene and Pliocene fossils. The first tier of foothills which rises north of the valley of the Santa Clara River consists of soft and pulverulent fossiliferous sandstone, in which Pliocene forms prevail. This is a very characteristic formation, and it is exposed at many places in the lower foothills which lie south of Mount Cayetana and the Sulphur Mountains. A collection of fossils from this sandstone shows the following vertical range:

Living, Quaternary	2
Living, Quaternary, Pliocene	10
Living, Quaternary, Pliocene, Miocene	9
Quaternary, Pliocene	1
Pliocene	2
New species	1

It is a general belief that in California there is a non-conformability between the Eocene and Miocene, and the Miocene and Pliocene formations.

SILVERTHREAD OIL DISTRICT.

2.1.49. It is about 6 miles north of Santa Paula, and at the southeastern end of Ojai Valley; in it are the following oil-wells, belonging to the Capital Crude Oil Co. of Los Angeles, the Sisar Oil and Asphalt Co. of Hueneme, Ventura County, and the Union Oil Co. of Santa Paula and Los Angeles. These wells are situated on a mountain slope which rises immediately to the northwest of the junction of Santa Paula and Sisar creeks, and forms the eastern side of a narrow valley through

which Sisar Creek flows. On the western side of that stream are the Sulphur Mountains, which attain an altitude of about 1,000′ above Sisar Valley.

2.1.50. Between the oil-wells and Sisar Creek are numerous springs of oil, which occur in two belts; one of them lies immediately east of the wells of the Capital Crude Oil Co., and the other south of the Sisar Oil and Asphalt Co.'s and the Union Oil Co.'s wells. (See sketch map, Fig. 33.) When the oil first exudes from the rocks, it spreads out in pools of tar (see Fig. 16); but the tar soon thickens to a viscous bitumen, which crawls down to Sisar Creek in streams of maltha and impure asphaltum. (See Fig. 17.) It also exudes from fissures in the hard sandstone. (See Fig. 12.) The summit of the mountain slope on which the Silverthread oil-wells are situated is marked on the sketch map as station E, and is about 700′ above Sisar Creek. The crest of this mountain slope consists for the most part of rather hard, reddish-brown sandstone. The few fossils these rocks contain are typically Eocene, notably *Cardita planicosta* and *Ostrea idriaensis*. The sandstone dips northerly. The rocks exposed north of station E, toward Echo Cañon Peak, are principally hard Eocene sandstone, with some dark-colored shale. In Echo Cañon, and in the cañon north of station E, and at several other places, there are springs of heavy oil issuing from the Eocene rocks. South of the Eocene formations, which are marked W in Fig. 34, are soft sandstones, bituminous in places, and slaty shale, which bleaches on exposure, and are marked Y. Beneath the coarse, grayish sandstone is a soft, fine-grained sandstone, and tough clay and clay-shales. The tough clay, as before mentioned, contains Eocene fossils, and some of which, although unclassified, are said by Dr. Cooper to resemble Miocene forms. This group of rocks is marked X. The rock exposures in the Silverthread oil district are very unsatisfactory, but such rock exposures as exist, together with the statements of well-drillers with regard to the kind of material they have penetrated in the district, warrants the conclusion that the rocks marked X and Y constitute the oil-yielding formations at this point. The occurrence of Miocene and Eocene fossils in the tough clays of the Silverthread district refers those clays to the same geological horizon as that to which the dark-colored shales at Tar Creek in the Sespe district belong.

2.1.51. The relative stratigraphic positions of rocks, marked, respectively, X, Y, and Z (Fig. 34), in the Silverthread district, and the sandstones containing typical Eocene fossils, which are exposed at station E, suggest a reversed fold, but no reduplication of strata was noted, and the relative position of the rocks referred to may be occasioned by faults; the rock exposures in the Sisar Valley are unsatisfactory, and deductions hazardous. The drilling records of the Union Oil Co. would throw some light on the situation, but they were not available.

2.1.52. *Bard Wells.* There are nine wells, 550′ to 800′ deep; total yield, 850 to 900 bbls. of oil a month. The territory on which these wells are situated lies immediately west of that belonging to the Capital Crude Oil Co. The drillers state that nearly all these wells showed a disturbed and crushed formation; and that in one of them asphaltum was penetrated for several feet. Some idea of the average life of the wells in the Silverthread district may be gathered from the following table:

FIG. 16. OIL-SPRING IN SISAR VALLEY.

FIG. 17. STREAM OF MALTHA IN SISAR VALLEY.

BARD WELLS—SILVERTHREAD OIL DISTRICT.

Number of Well.	When Drilled.	Depth.	Daily Yield when Completed.	Daily Yield in June, 1895.
		Feet.	Bbls.	Bbls.
2	1892	350	14	5
3	1892	350	5	3
4	1894	450	8	5
5	1893	420	20	6
6	1893	420	12	3½
7	1893	350	8	1½
8	1893	750	3	1
9	1893	750	5	1½
10	1894	658	3	1½

Two varieties of oil are obtained from these wells; namely, an oil of high specific gravity from the shallowest wells, and an oil of somewhat lower specific gravity from the deeper wells.

2.1.53. *Capital Crude Oil Co.* has eleven wells, 400′ to 750′ deep; also one abandoned well (the Webber), near Santa Paula Creek. No definite record of the strata penetrated was kept, but the well-drillers state that in the most northern of the wells they passed through sandstone for about 380′, at which depth oil-bearing shales were reached. They say that, farther southward, the strata penetrated are principally blue shales, tough blue clay, red rock (iron-stained shale), and soft sandstones; and that the oil was either in the hardened shales or in their sandstone strata, which interstratify the soft clayey shales. In June, 1895, ten wells belonging to the Capital Crude Oil Co. were being pumped, and yielded about 990 bbls. of oil a month. These wells yield two grades of oil. (See oil analysis.)

2.1.54. *Union Oil Co.'s Wells.* (See sketch map, Fig. 33.) These are situated immediately west of the Bard wells. There are two wells more than 900′ deep, one 600′, one 500′, and five varying from 60′ to 200′ in depth. In June, 1895, eight of them were being pumped, and yielded, all told, 600 bbls. of oil a month. Three kinds of oil are obtained from these wells: a heavy black oil, a brown oil, and a green oil. (See oil analysis.) The black oil is obtained from the shallow wells.

2.1.55. *Oil-Wells South of Sulphur Mountains.* These wells are at the southern base of the Sulphur Mountains, and at 800′ to 1,000′ altitude. They are as follows: Adams Cañon, Aliso Cañon, Salt Marsh, Scott & Gillmore, and Wheeler Cañon wells. All these wells, except those in Aliso Cañon, and perhaps some of the wells in Wheeler Cañon, are situated a short distance north of the axis of the anticlinal fold, which, as shown in cross-section, Fig. 34, lies south of the fold penetrated by the wells in the Silverthread district.

2.1.56. *Adams Cañon Wells.* It is said that twenty-nine wells have been drilled in this cañon, varying from 200′ to 2,780′ in depth, and yielding from 5 to 1,000 bbls. of oil a day. In June, 1895, they were nearly all exhausted, and only three wells were being pumped, which were reported to yield, all told, about 900 bbls. of oil a month. As the Adams Cañon wells have been, and are yet, the most important group on the south side of the Sulphur Mountains, a brief description of some of them may be of interest. In the east fork of Adams Cañon, about a mile west of Santa Paula Creek, there are several acres covered with brea. In the eastern end of this brea-bed a well was drilled at an early

day, which is said to have been productive for many years. Several other wells, more or less productive, were drilled in the east fork of Adams Cañon. The most important one was known as the Bradford well, said to be 600′ deep, and yielding 300 bbls. of oil a day for many months; but its yield gradually diminished, and at the end of three years the well was exhausted. The most interesting of the Adams Cañon wells are situated in the central fork of Adams Cañon, otherwise known as Wild Bill Gulch. The well from which this cañon takes its name is 700′ in depth, and was sunk in 1882. The formation penetrated is soft clayey shale, with strata of sand. Oil was struck shortly before reaching the greatest depth attained. This well yielded 75 bbls. of oil daily for a year, when it commenced to fail, and at the end of three years went dry.

2.1.57. No. 27 is situated 75′ south of the Wild Bill well. Similar strata to those encountered in the Wild Bill well were passed through to 1,800′ in depth. From that point to a depth of 2,780′ the formation was principally sand. At 1,000′ depth the well yielded 25 bbls. of heavy black oil a day, but no gas. At 2,000′, a heavy, grass-green oil was obtained, which, when exposed to the air for a few hours, became thick and viscous. Between the depths of 2,700′ and 2,780′, a light-green oil of about 27° B. and much gas were obtained from a dark-brown sand formation. When first pumped, it yielded about 60 bbls. of oil a day. It was pumped continually for three years, and gradually diminished until 1895, when it yielded daily only 5 bbls. of green oil of low specific gravity.

2.1.58. No. 16 is about 125′ southwest of the Wild Bill well. The formation passed through varies from dark-brown to light-colored sand, yielding much gas. A brown oil of high specific gravity was struck at 330 in depth. At 875′ the oil shot above the top of the derrick. This well is said to have flowed at the rate of 1,000 bbls. of oil a day for ten days, when it was capped under a pressure of 1,500 lbs. to the square inch. In a few weeks the flow of oil ceased, and the well was pumped. At first it yielded 300 bbls. of oil a day, but at the end of one year the well was exhausted.

2.1.59. Seven wells were sunk in Wild Bill Gulch; it is said that only Nos. 28 and 29 appeared to affect each other, and they were about 200′ apart. No. 28 was 850′ deep, and yielded 25 bbls. daily until No. 29 was completed, when it went dry in twenty-four hours thereafter. In it water was struck at 200′ depth. No. 29 was 975′ deep, and water was struck at 200′ depth. At 975′ it was pumped, and yielded at the rate of 60 bbls. a day for a short time, and then 25 bbls. daily for five years.

2.1.60. In 1887 a well was drilled in west fork of Adams Cañon, and about one quarter of a mile west of Wild Bill Gulch. It is said that, although this well is 1,400′ deep, when completed it yielded only 5 bbls. of oil a day, and that it failed in a few months.

2.1.61. *Aliso Cañon wells* are about 4 miles west of those in Wheeler Cañon and about 10 miles in an air-line from Santa Paula. These five wells, 600′ to 700′ deep, are said to be producers of oil accompanied by much water. In May, 1895, they were not being pumped.

2.1.62. *Salt Marsh Cañon wells* are situated about one half mile southwest of the well in the west fork of Adams Cañon, and consist of nine wells drilled in 1887, and varying from 250′ to 1,600′ in depth. It

is said that the formation is dark-colored shale and sand, and that they yielded 200 bbls. of oil a day for more than a year, but that the yield gradually diminished, until in 1895 three wells only were being pumped, which yielded, all told, 300 bbls. of oil a month.

2.1.63. *Scott & Gillmore wells*, seven in number, are about one half mile west of Santa Paula Creek, and are 300′ to 1,100′ deep; total yield, 200 bbls. of oil a month. The oil varies from a light-brown oil to maltha; the oil of the lowest specific gravity, *i. e.*, the light-brown oil, is obtained from strata which are the lowest in point of vertical range.

2.1.64. *Wheeler Cañon wells* are more than a mile southwest of the wells in Salt Marsh Cañon. It is said that five wells, from 200′ to 900′ deep, were drilled in this cañon; and that the chief oil-bearing stratum was struck at 90′ depth; also, that the best well was only 250′ deep, and that it yielded 30 bbls. of oil a day for six months, and then went dry. In Wheeler Cañon there are extensive deposits of calcareous tufa, from which specimens of *Helix traski* (see table of fossils) were obtained. There are similar rocks at other places in the Sulphur Mountains, and many of the springs which issue therefrom form a calcareous deposit.

2.1.65. Many of the wells in the Silverthread district and on the southern side of the Sulphur Mountains yield considerable gas. It is used for steam-boilers and for domestic purposes.

OIL-WELLS ON SOUTHWESTERN SLOPE OF MOUNT CAYETANA.

2.1.66. *The O'Hara oil-wells* are situated three quarters of a mile east of Santa Paula Creek, and at about 1,130′ elevation. (See Fig. 6.) They pierce similar strata to those south of Sulphur Mountains. They consist of five wells, varying from 430′ to 1,170′ in depth, and yield, all told, about 400 bbls. of oil a month.

2.1.67. The following records of the two deepest wells were kindly put at the disposal of the Mining Bureau:

Well No. 1. Completed December 2, 1892, yielding 900 bbls. of oil monthly. In June, 1895, it yielded 300 bbls. of oil per month.

To	45′	depth,	14″ casing. Clay and light-colored shale.
"	70′	"	Dark shale, with a little water.
"	80′	"	Water, with a little gas.
"	120′	"	Dark shale, with streak of brea; some water.
"	200′	"	12½″ casing. Slate and shale.
"	255′	"	Shale.
"	275′	"	Thin stratum of hard rock.
"	300′	"	8⅝″ casing (screw). Soft shale.
"	415′	"	Shale and brea.
"	525′	"	Sand, with gas.
"	575′	"	Sand and slate; more gas and a little oil.
"	650′	"	6⅝″ casing. Hard, dark shale, with thin streaks of sand and brea; some oil.
"	655′	"	Sand, with water.
"	705′	"	Dark-colored sand, with gas.
"	735′	"	More water, with traces of oil.
"	805′	"	Hard, close, dark-colored sand, with a little oil.
"	817′	"	Dark-colored sand; good showing of oil; during 8 days pumped 22½ bbls. a day.
"	895′	"	Dark-colored sand (making 90′ of oil-sand in one stratum).
"	950′	"	Shale and slate.
"	965′	"	Sand, with gas and oil.
"	1,005′	"	Shale and light-colored slate.
"	1,100′	"	Oil-sand.
"	1,120′	"	4½″ casing.
"	1,155′	"	Oil-sand.
"	1,170′	"	Slate.

Well No. 2 is about 700′ southwesterly of the preceding. In June, 1895, it yielded 1 bbl. of heavy oil daily, said to come from between 190′ and 215′ depth.

To	20′ depth,	14¼″ casing. Dark-colored sand.
"	60′ "	Hard, white sand, followed by softer sand.
"	75′ "	12″ casing. Harder sandstone; brea streak; showing of heavy oil and a little water.
"	85′ "	Showing of light, amber-colored oil.
"	100′ "	Hard sandstone; heavy oil.
"	170′ "	Shale, caved badly.
"	190′ "	10⅝″ casing. Light-colored sandstone.
"	215′ "	Dark sand. Heavy oil rose to within 100′ of the surface. For a few days 8 bbls. of oil a day were pumped, but afterward diminished to 3 bbls.
"	300′ "	Light-colored, soft shale, with streaks of white sand.
"	320′ "	Dark-colored shale (caves badly).
"	390′ "	Sandstone, with thin strata of shale and a little gas.
"	520′ "	Sand and shale.
"	570′ "	Shale and light-colored sand.
"	620′ "	6¾″ casing. Sandstone and gas; shale (caves badly).
"	670′ "	Dark-colored sandstone.
"	775′ "	Very hard, white sand.
"	790′ "	5¾″ casing.
"	854′ "	Sandstone.
"	854′ "	Soft sandstone.
"	860′ "	Sand, with some gas and oil and much water.
"	870′ "	Running sand.
"	965′ "	Shut down six weeks; hole filled 100′ with sand.
"	1,105′ "	4⅝″ casing. Hard, white sand.
"	1,125′ "	Running sand.

2.1.68. Extending east from the Jones (O'Hara) oil-wells the exposed formations consist of dark-colored shales and soft sandstones, which crop out all the way up Bear Cañon. In some places petroleum seeps from them.

2.1.69. *The Grayham well* is about 4 miles east of the O'Hara wells and a short distance west of Timber Cañon. It is said that this well is 275′ deep; that it penetrates a soft grayish sandstone, and that it can be made to yield 6 bbls. of oil in twenty-four hours.

2.1.70. TOTAL YIELD OF OIL-WELLS NORTHWEST OF SANTA PAULA.

Oil-Wells.	No. of Wells.	Depth.	Monthly Yield.
		Feet.	Bbls.
Capital Oil Co. wells	11	400 to 750	990
Bard wells, Sisar Oil and Asphalt Co.	9	550 to 800	900
Union Oil Co.'s wells, in Sisar Cañon	9	60 to 900	600
Scott & Gillmore wells	7	300 to 1,100	200
Union Oil Co.'s wells, in Adams Cañon	3		900
Union Oil Co.'s wells, in Salt Marsh Cañon	3		300
O'Hara wells, in Bear Gulch	5	430 to 1,170	400
Total monthly yield			4,290

CHAPTER II.

Oil-Tunnels.

2.2.01. All the productive oil-tunnels in the Sulphur Mountains district are situated on its southern slope. It will be observed by examining Figs. 33 and 34, that the oil-tunnels penetrate strata which overlie the rocks pierced by the oil-wells on the south side of the Sulphur Mountains; also, that the oil-tunnels are situated immediately south of the solfataric line, which, as before mentioned, probably marks a fissure or fault traversing the Sulphur Mountains in a course which is nearly, but not quite, coincident with the strike of the formation. Indeed, the Orne tunnel terminates in crushed shales, almost within the southern limits of the solfataric line previously mentioned.

2.2.02. An inspection of Figs. 18, 19, and 20, which respectively show the Pinkerton, Good, Magie, and some of the Farrell tunnels, will give those who wish closely to follow the matter a good idea of the character of the strata penetrated by the oil-tunnels on the southern slope of the Sulphur Mountains. These strata consist of dark-colored clay shale and soft sandstone, with an occasional hard calcareous stratum. The shale becomes slaty as the before-mentioned solfataric line is approached. In these tunnels, the oil is usually struck in thin strata of sandstone, or it oozes from little fissures or cracks in the shale or slate, and sometimes it exudes from between the laminæ of the slaty shale; it is usually accompanied by sulphureted water. For the most part, the oil is green, but heavy black, brown, heavy and light green oils are found at no great distance from one another. Some of the strata penetrated by these tunnels yield much gas. When work is in progress, the tunnels are illuminated by reflected sunlight (Fig. 21) or by incandescent electric lights. The blasts are usually discharged by electricity, and water-blasts are used to ventilate the workings. The cost of running these tunnels is about as follows: \$1 50 per foot for the first 100′, and \$1 per foot more for every additional 100′, exclusive of the cost of timbering. Each foot of tunnel requires one 2″x 12″x 16′ plank for posts and caps, and sometimes lagging is needed. The tunnels are usually 4′ wide on the bottom and 3′ wide on top, and about 6′ high. A foot-board and a track run the entire length of the tunnels. The track is made either of iron or 3″x 4″x 16′ pine scantling. For sleepers, a 2″x 12″x 16′ plank is used for every 16′ of track. The oil and water flow down a gutter in the floor of the tunnel to a separating tank, which usually holds 10 bbls. In the separating tank, the oil rises to the surface of the water, and is drawn off by a pipe-line to a receiving tank, while the water escapes from an outlet at the bottom.

The following tunnels are shown on Figs. 23 and 24:

2.2.03. *Pinkerton Lower Tunnel.* It is 320′ in length. When completed in 1894, it yielded 45 bbls. of oil a month. In 1895 it yielded per month 30 bbls. of oil of high specific gravity. The principal source is a sandstone stratum 8½″ in thickness, which is traversed by crevices ⅛″ to ¼″ wide. The oil is accompanied by gas and sulphureted water. Between this sandy stratum and the end of the tunnel, oil and sulphureted water seep through cracks in the walls and in the floor of the tunnel.

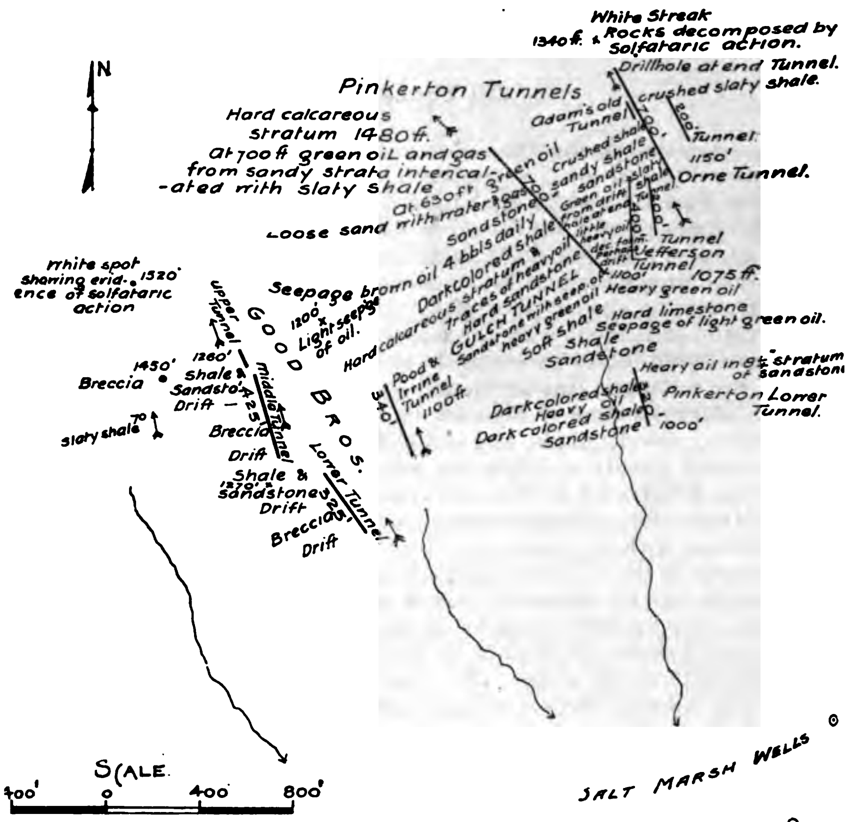


FIG. 18. THE PINKERTON AND THE GOOD BROTHERS' OIL-TUNNELS.

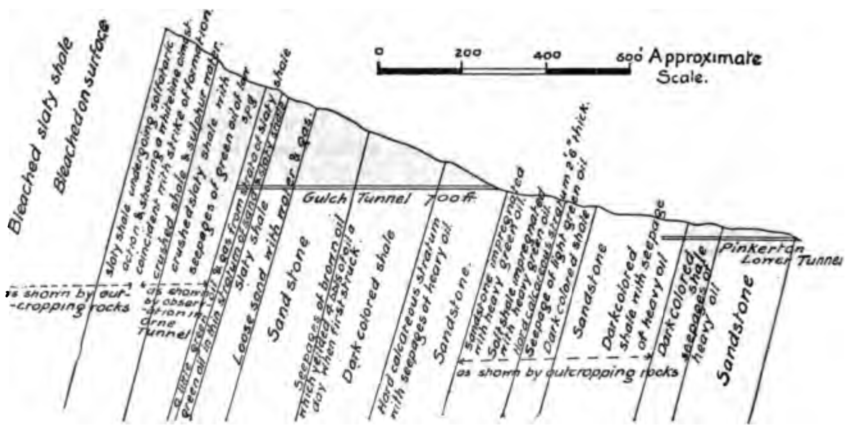


FIG. 19. FORMATIONS PENETRATED BY THE PINKERTON TUNNELS.

2.2.04. *Pinkerton Middle* (*Gulch*) *Tunnel.* It is 700′ in length. It is distant about 400′ N. 15° W. from the end of the Pinkerton lower tunnel, and is about 100′ higher up the mountain. Between the two points the rock exposures show the formation to be that represented in Figs. 18 and 19. In the Gulch tunnel the formation is shale and soft sandstone; the shale is more slaty than it is in the lower tunnel, and some strata contain the bones of fish. There is much gas. At 125′ a small amount of black oil in shale was first encountered. At 400′ a heavy brown oil was struck at the contact of shale and sandstone. At first this oil seepage yielded 4 bbls. of oil daily. At 630′ a thin stratum of loose sand yielded much gas and sulphureted water, and the strata are vertical. For the next 10′ a light green oil of low specific gravity oozes from sandy strata which are separated by slaty shale. At the end of the tunnel a slaty shale gives out a little green oil and much gas. For the first year after its completion, in 1892, this tunnel yielded 150 bbls. of oil a month. In 1895, the yield was 90 bbls. of oil a month.

2.2.05. *Jefferson Tunnel.* It is 400′ in length, and was completed in 1893. It appears to be run in consolidated drift, or decomposed rock. At 100′ green oil was struck, and a little oil seeps out here and there throughout the entire length of the tunnel, at the end of which a 35′ well has been drilled. When first completed this well yielded 210 bbls. of oil a month; in 1895 it yielded 50 bbls. of oil a month.

2.2.06. In 1895 a 200′ tunnel has been run about 15′ N. 50° W. from the mouth of the Jefferson tunnel, and about 20′ higher up the mountain. The formation is slaty shale. There is a 45′ drill-hole at the end of the tunnel, which yields 30 bbls. of rather heavy green oil a month; no water.

2.2.07. *Orne Tunnel.* It is 700′ in length, and was completed early in 1895. The mouth of this tunnel is about 200′ N. 25° E. from the tunnel last described, and is about 40′ higher elevation. It penetrates soft sandstone and slaty shale. At 100′ a heavy green oil was struck in sandstone. Between 300′ and 400′ a green oil of low specific gravity oozes from strata of sandy shale. At the end of the tunnel the shale is crushed and yields sulphureted water and brown oil of high specific gravity. At the end of the tunnel a 25′ hole has been drilled, from which sulphureted water and a little oil flow. At its completion this tunnel yielded 120 bbls. of oil a month for three months. In 1895 the flow was 50 bbls. a month. As before mentioned, the end of this tunnel penetrates crushed rocks which underlie the solfataric line previously described.

2.2.08. *Adams* (*Old*) *Tunnel.* It is 75′ long, and was completed, it is said, in 1880. It is distant about 400′ N. 25° W., and about 100′ above, the mouth of the Orne tunnel. The formation appears to be slaty shale, but is much decomposed; in many places the surface of the walls and the timbers are coated with small, flat, lustrous crystals, which appear to be the thickest where the gas is the strongest. Before the Orne tunnel was completed the Adams (old) tunnel yielded 30 bbls. of heavy oil a month. In 1895 it yielded practically nothing.

2.2.09. A 200′ tunnel has been run a short distance N. 12° E. of the Orne tunnel, in slaty shale, at the end of which a heavy green oil was struck. When first completed it yielded 120 bbls. of oil a month; in June, 1895, it yielded about 15 bbls. of oil.

2.2.10. *Good & Irwin Tunnel.* It is 340′ in length, and situated

2.2.21. At the end of the tunnel a soft sandstone was struck, which yielded a little oil and much gas. Work was still in progress in June, 1895, when the yield was 60 bbls. of oil a month, with some sulphureted water.

2.2.22. A few fossils were obtained from the dark-colored shale in the Magie and Farrell & Kimball tunnels, and they were classified by Dr. J. G. Cooper as a mixture of Eocene and Miocene forms.

2.2.23. *The Water-blast* here used (Figs. 21 and 23) consists of a sheet-iron column, C B, about 35′ long, and supported by a light derrick, and enters the top of wooden box, D D′ E E′, which is 6′ long, 14″ wide, 14″ high at one end and 10″ high at the other.

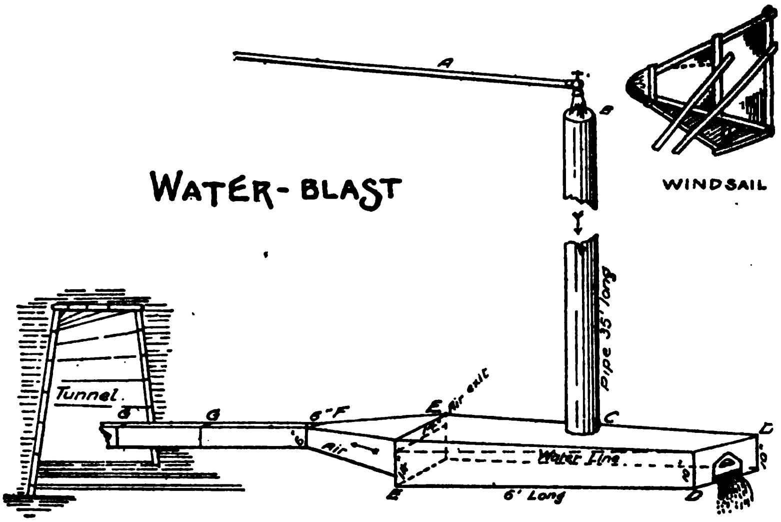


FIG. 23.

A 6″ x 6″ conduit of dressed lumber, G G F, is connected by a tapering box, F E, with the air-end of the box E E′ D D′, which is provided with a ½″ slot, H, with a sliding gate to regulate the escape of the water. The water is turned into the top of the column from a ½″ nozzle, A, under a 200′ head. The air is carried down with the water and forced through the tapering box and conduit to the end of the tunnel. The Magie 560′ tunnel fills with gas in a few hours, and it takes the water-blast about half an hour to purify the air so that work can safely be commenced. At this tunnel a combination track and foot-board is used. The foot-board is a plank 2′ wide. The track is formed of 1″ x 3″ pine strips, which are nailed broadside down along the edges of the foot-board.

2.2.24. There are six tunnels in the west branch of the middle fork of Salt Marsh Cañon, which yield, all told, about 100 bbls. of oil a month.

2.2.25. *Adams Cañon Tunnel.* It is 900′ long, and is situated at the northern end of the west fork of Adams Cañon. It penetrates formations very similar to those noted at the lower west Pinkerton tunnel, and yields sulphureted water and traces of oil.

2.2.26. *Major Moultre Tunnel.* It is 650′ long, is situated at the northern end of a gulch which extends in a northerly direction from the east fork of Adams Cañon, and was run to tap a 300′ well, which, when

Fig. 21. Water-Blast and Reflector at Magie Tunnel

Fig. 22. Las Conchas Mine at Carpinteria.

first drilled, yielded at the rate of 30 bbls. a day. This tunnel, near its end, penetrates strata which show evidence of solfataric action where they crop out at the surface. The formation is as follows:

Crushed shale	100′
Reddish shale	50′
Slaty shale, with thin strata of hard limestone, yielding 1 bbl. of brown oil daily	50′
Hard shale and limestone ledges, yielding sulphureted water and much gas	200′
Hard shale, with flinty nodules, yielding a green oil	100′
Thin strata of black slaty shale	50′
Slate in strata of 1½′ thick	100′

On exposure this slate broke into thin laminæ. At the end of the tunnel is a slaty shale, which yields green oil and gas. It is said that this tunnel was completed in 1889, when it yielded 900 bbls. of oil a month. In 1895 it flowed at the rate of 50 bbls. of oil a month.

2.2.27. *Wheeler Cañon Tunnels.* It is said that there are three 600′ tunnels in Wheeler Cañon, whose combined yield is 300 bbls. of oil a month.

2.2.28. *Parker & Orne Tunnel* is situated in Mud Creek Cañon, and was completed in 1890. It is said to be 100′ long and to have yielded 60 bbls. of heavy oil a month. It is now partly caved and no oil flows from it.

2.2.29. YIELD OF OIL-TUNNELS NORTHWEST OF SANTA PAULA.

Oil-Tunnels.	No. of Tunnels.	Length.	Monthly Yield.
		Feet.	Bbls.
Major Moultre tunnel, in Adams Cañon	----------	650	50
Farrell & Kimball's, in west and central forks of Salt Marsh Cañon	9	50 to 325	190
Good tunnels, in east branch of Salt Marsh Cañon	13	60 to 430	15
Magie tunnels, in west fork of Salt Marsh Canon	4	60 to 560	238
Pinkerton tunnels, in east branch of Salt Marsh Cañon	----------	200 to 700	255
Union Oil Co.'s, in Wheeler Cañon	3	600	300
Total monthly yield	----------	----------	1,048

Total monthly yield from oil-wells in Ventura County (see 2.1.70)	4,290 bbls.
Total monthly yield from oil-tunnels in Ventura County (see 2.2.29)	1,048 bbls.
Grand total	5,338 bbls.

CHAPTER III.

General Remarks.

2.3.01. A study of the foregoing maps and observations leads to the conclusion that two tunnels may run parallel to each other and penetrate the same strata, and yet the oil seepages struck in one tunnel may be absent from the other. When oil is obtained by cutting through sandy strata between slate walls, such as the sandy strata yielding the green oil near the end of the Gulch tunnel, it is probable, other things being equal, that similar oil would be obtained in other tunnels, if they penetrated these particular strata, and were not far distant from the tunnel in which oil was first obtained. This appears to be the case in the Gulch and the Orne tunnels with regard to the strata named. On the other hand, it will be observed that nearly all the tunnels on the south

side of Sulphur Mountains penetrate very similar strata which have pretty much the same position in point of vertical range, but that the yield of the different tunnels is dissimilar. In a general way, the most productive strata are those nearest to the solfataric line previously mentioned, in the vicinity of which the rocks are much fractured. An examination of the walls and the breasts of the tunnels shows that the principal source of the oil is from crevices in the rocks, and that the course of such crevices is apt to be erratic.

2.3.02. There is one feature in connection with the oil-wells northwest of Santa Paula which has not yet been mentioned. It is this: Although, as previously mentioned, the oil-lines follow the strike of the rocks, it is stated that very different results are obtained from wells situated nearly on the same line of strike and at no great distance from one another. It is probable that, in some instances, the oil-bearing rocks have been missed in consequence of the strata beneath the surface dipping at a much greater angle than their outcropping edges indicate; for a very thin strata of tough clay or clay-shale would suffice to shut off the oil. The most important fact is that all the productive wells northwest of Santa Paula penetrate dark-colored shales and soft sandstones which, in the main, are similar to the rocks penetrated by the wells at Tar Creek, Four Forks, Brownstone, and the Kentuck oil claims; moreover, the fossils obtained indicate that the formations at these places belong to the same geological horizon, namely, the Oligocene.

2.3.03. The territory in which the Bardsdale, Eureka, Fortuna, and Torrey Cañon oil-wells are situated has not yet been investigated, but the following statistical information was obtained:

2.3.04. *The Bardsdale wells*, about 3 miles south of Fillmore, are twenty-two in number, whose monthly yield is about 3,000 bbls.

2.3.05. *The Eureka Oil Co.'s wells* are in Limekiln and Smith's cañons, and are about 1½ miles south of Piru station, on the S. P. R. R. They consist of four wells, 400′ to 570′ deep, and are said to yield at the rate of 600 bbls. of oil a month.

2.3.06. *The Fortuna wells* are situated in Hopper Cañon, about 4 miles north of Buckhorn station, on the S. P. R. R. They consist of eight wells, ranging from 125′ to 400′ in depth. It is said that, owing to the low price of oil, these wells were shut down in the spring of 1895, and that only 500 bbls. were pumped from them during that year.

2.3.07. *The Torrey Cañon wells* are about 3 miles south of Piru station, on the S. P. R. R. They consist of nineteen wells, which yield about 4,500 bbls. a month.

2.3.08. *Petroleum produced in Ventura County during 1895:*

	Bbls.
Capital Crude Oil Co.	11,000
Eureka Oil Co.	5,711
Fortuna Oil Co.	500
Jones Oil Co	3,613
Scott & Gillmore (represented by Union Oil Co.)	1,000
Sisar Oil Co.	10,800
Union Oil Co. wells, in the Sespe district, Sisar Valley, Torrey Cañon, and on southern slope of Sulphur Mountains	200,000
Oil-tunnels on southern slope of Sulphur Mountains, owned respectively by Union Oil Co., R. H. Magie, Good Bros., W. Pinkerton, and Farrell & Kimball	12,000
Total	244,624
Value*	$244,624

* Estimated at current price of petroleum in Ventura County for 1895.

2.3.09. The Union Oil Co., of Santa Paula, handles nearly all the oil produced in Ventura County. They have established a new system of pipe-lines connecting Ventura with the oil-fields in which they are interested. A trunk line of 4″ pipe connects Ventura with Sespe, with 3″ branches running to Torrey Cañon and Bardsdale, and 2″ branches to the other oil-fields. This system comprises, all told, about 100 miles of pipe.

PART III.

THE REGION BETWEEN SANTA PAULA, VENTURA COUNTY, AND SUMMERLAND, SANTA BARBARA COUNTY.

CHAPTER I.

Geology.

3.1.01. The bleached Miocene shales of the Sulphur Mountains can be traced westward to the Cañada del Laga. On this ranch, about 5 miles north of Ventura, is the Brea Cañon, or Weldon, asphalt mine. In September, 1895, the developments consisted of a 50′ tunnel, partly caved, and a 50′ incline. At the mouth of the tunnel is a 2′ vein of smooth, black asphaltum, said to assay about 40% asphaltum. It dips S. 65° E. at an angle of about 42°. The wall rock is tough clay, containing Quaternary fossils. (See table of fossils.)

3.1.02. Through the western part of the Cañada del Laga the Ventura River has cut what appears to be a hard sandstone, probably Eocene, on which a bleached shale seems to rest practically conformably, although no point of actual contact was observed. These formations dip to the south. Nearer to Ventura, and apparently resting conformably on one another, are whitish sandstones, sandy and clayey strata, and conglomerate. From the whitish sandstones a few fossils of Pliocene age were obtained. The physical appearance of these sandstones resembles the whitish sandstones described as capping the ridge which traverses the eastern side of the Sespe district and the southern slope of Mount Cayetana; and the clayey and sandy strata resemble those formations in Santa Paula Creek. Farther southward, toward Ventura, are soft, drab-colored sandstones, and fossils obtained therefrom are referred by Dr. J. G. Cooper to either the latest Pliocene or the Quaternary period. Five miles northwest of Ventura is the asphalt mine of the Ventura Asphalt Co. (See article by Prof. E. W. Hilgard in our Xth Report, p. 763.) It was idle during 1895. The late Tertiary formations extend westward from Ventura to the hills east of Rincon Creek, where the bleached shales again come to view. (See sketch map, Fig. 35.)

3.1.03. In 1895 solfataric action could be noted at more than one place in the bluffs at the southern base of Mount Hoar, which rises to the east of Rincon Creek, near the line between Ventura and Santa Barbara counties. At these places the rocks are perceptibly warm, and are impregnated with saline material. It is evident that there is intense chemical action taking place in these shales. A few years ago, a 70′ tunnel was run in these bluffs, which is said to have shown a tempera-

ture of 130° F. It is also stated that the following phenomenon was observed in a dump composed of fragments of these shales, as described by A. S. Cooper, C.E., in the "Scientific American," of December 30, 1893: "About 13 miles east of Santa Barbara, an excavation was made, in the bluffs facing the ocean, for the road-bed of the Southern Pacific Railroad; and the gray shale from the excavation was thrown over the bluff, forming a conical-shaped pile composed of pieces of shale containing from one to eight cubic inches. Water could easily penetrate the broken shale and air could freely circulate through the mass. When the winter rains fell upon this pile of shale, chemical action commenced, producing sufficient heat to vitrify and weld the shale together. A large part of the shale was burned to a red porcelainite, and the remainder was turned to a buff color, graduating into deep shades of red."

3.1.04. In August, 1895, the pile of fragments of shale referred to could be seen by the side of the railroad track. Many of the fragments of the shale were partly fused, and the whole pile had the appearance of having been subjected to intense heat. As these shales did not appear to contain an appreciable amount of iron pyrites, the writer sought for specimens which had not been exposed to the air, to see if their constituents were such as could by oxidation produce such intense heat as that which had been observed in the pile of shale. The point nearest to the pile of shale from which a specimen which had not been "weathered" could be obtained, was the Higgins oil-well, of Carpinteria. The following analysis of the shale from this well throws no light on the question involved:

Silica (SiO_2)	41.42%
Iron (FeO) estimated as	8.74
Alumina (Al_2O_3) estimated as	7.14
Calcium oxide (CaO)	10.72
Magnesium oxide (MgO)	3.50
Carbon dioxide (CO_2)	15.98
Bituminous matter	6.32
Moisture	6.18
	100.00

Under the microscope this shale shows finely disseminated bituminous matter and marine diatoms.

3.1.05. The bleached shales are much fissured in many places, and the faults and fissures are frequently filled with bitumen. In some places these shales are interstratified with bituminous sand. At one point strata of this sand show more than 20′ in aggregate thickness. These sands at their outcrop are blackened by dry pulverulent bituminous matter, which probably is a residue from oils which have lost their lighter hydrocarbons by evaporation. It is not unlikely that these sands would yield oil if penetrated at a suitable depth beneath the surface.

3.1.06. Resting non-conformably on the bleached shales are soft sandy strata containing numerous fossils of late Pliocene or Quaternary age. In Carpinteria Valley this soft, sandy formation is penetrated by several water-wells, notably one on the Higgins ranch, from which a small collection of fossils was obtained. The best exposure of this formation is on the west bank of Rincon Creek, a short distance north of the railroad track. At this point a collection of fossils was

made, thirty-two specimens of which were classified, and showed the following range:

Living, Quaternary	15
Living, Quaternary, Pliocene	12
Living, Quaternary, Pliocene, Miocene	9
Quaternary	1
Pliocene, Miocene	1
Undetermined	2

3.1.07. A short distance north of the junction of Casitas and Rincon creeks are the Santa Ynez Mountains, which enter Santa Barbara from Ventura County and extend westward. In Sec. 24, T. 4 N., R. 25 W., M. D. M., about 2 miles north of Shepherd's hotel, there are springs of heavy oil and sulphureted water, on which oil-claims have been located. The formation consists of hard sandstone and dark-colored shale, from which several specimens of *Ostrea idriaensis* were obtained, which show the formation to be of Eocene age.

BITUMINOUS DEPOSITS IN SANTA BARBARA COUNTY.

3.1.08. The Punta Gorda asphalt mine is rather more than a mile east of Rincon Creek, less than a quarter of a mile north of the S. P. R. R., and at about 150′ altitude. The workings consist of a tunnel about 140′ long, and a 100′ shaft. The tunnel cuts through a vein of asphaltum which has a strike of N. 20° W. The thickness of the vein in the tunnel varies from 10″ to 2′, and dips S. 60° E. at an angle of about 75°. The wall rock is the bituminous shale previously mentioned. At the mouth of the tunnel the shale is much disturbed, and in the tunnel it shows a dip of S. 30° W., at an angle of about 70°. The prevailing dip of the formation north of the tunnel is N. 10° E., at an angle of about 80°. The shaft has been sunk on the vein, which shows about 13′ maximum thickness. The asphaltum is a uniformly black mass, which exhibits a slightly granular structure. The following assays of asphaltum obtained in the Punta Gorda mine are from the records of the company:

From the 40′ level, by Prof. Geo. E. Colby, University of California, Berkeley:

Loss at 212° F.		0.83%	
Hydrocarbons	Equal 28.50% bitumen	18.06	
Fixed carbon		10.44	
Ash		70.67	
			100.00%

The asphaltum contains 28.06% fixed carbon.

From the 60′ level, by C. A. Ogden, chemist:

The sample of bituminous rock contained:

Bitumen	28.53%	
Silica	51.64	
Clay	4.76	
Calcium sulphate	2.45	
Calcium carbonate	11.96	
Magnesium carbonate	0.55	
Not determined	0.11	
		100.00%

The pure bitumen showed the following condition when treated at various temperatures:

Loss of oils at 212° F.	2.65%	
Loss of oils at 212° to 480° F.	6.95	
		9.60%

FIG. 24. ALCATRAZ ASPHALT REFINERY AT CARPINTERIA.

FIG. 25. THE COLD-WATER ANTICLINE ON MT. CAYETANA, FROM SESPE CAÑON.

Above 480° F.	40.72%	
Carbon	49.68	
		90.40%
		100.00%

From the 85′ level, by Prof. Geo. E. Colby:

Loss at 212° F.		0.71%	
Hydrocarbons	Equal 29.91% bitumen	18.72	
Fixed carbon		11.19	
Ash		69.38	
			100.00%

The asphaltum contains 37.30% fixed carbon.

3.1.09. *The Rincon asphaltum mine* is situated on the Rincon ranch, about 1 mile northeast of the Punta Gorda mine, and at about 900′ altitude. At this point soft Pliocene sandstones rest non-conformably on the Miocene shales. The workings consist of a tunnel and an open cut. The tunnel has been run N. 80° E. and cuts through a body of sand which is impregnated with heavy oil, and about 4′ in thickness. The walls of the tunnel are soft sandstone, containing a few fossils. Thirteen specimens were obtained from this formation, and classified. They show the following range:

Living, Quaternary	2
Living, Quaternary, Pliocene	7
Living, Quaternary, Pliocene, Miocene	4
Pliocene	1

3.1.10. About 50′ S. 30° E. from the mouth of the tunnel there is an open cut about 10′ deep, which shows a body of impure asphaltum, and appears to be an extension of the body of oil-soaked sand and asphaltic material which has been cut through by the tuunel.

3.1.11. In the railroad cut near the mouth of Rincon Creek a soft bituminous sand is exposed, which contains a few fossils and dips to the north at an angle of about 30°. This sand is several feet in thickness, but the lighter oils have almost entirely evaporated from it, leaving it dry and pulverulent.

3.1.12. *The Las Conchas mine and asphaltum works* (see sketch map, Fig. 35, and Figs. 22 and 24) are situated on the seashore at Carpinteria. The mine consists of a body of bituminized sand which covers about 75 acres, and which has been estimated by boring to be more than 25′ in average thickness. The sand is soaked with maltha, derived from the bituminous shale on which it rests. The prevailing dip of these shales is N. 10° W., and the angle of inclination is for the most part 70° or more. The bituminized sands appear to be horizontal, as they dip to the northwest at a very slight angle. The process of mining is as follows: The surface soil, consisting of 6′ to 8′ of loam, is removed by hydraulic washing; a thin stratum of yellow clay, overlying the bituminous sand, is then stripped off; the sand is mined with hot spades, and conveyed by cars, which are hauled by a cable up an incline track, to the upper floor of the asphaltum refinery, where it is dumped into a "mixer," consisting of a steam-jacketed cylinder, in which revolving arms break the lumps. From the mixer the sand falls into vats of boiling water; the maltha floats and the sand sinks to the bottom, where revolving "worms" carry the sand to a hopper, feeding a "bucket conveyor," which conducts the sand through a flume to the point of discharge. When each bucket reaches the point of discharge, it is played on by a jet of water to free it from the sand. The maltha, called "crude

flux," flows from the surface of the water through a flume to a tank, whence it is pumped into a storage tank at a higher elevation. From the storage tank the "crude flux" runs by gravity into two refining kettles of 15 tons capacity each, where it is subjected for twenty hours to a high temperature, commencing at 100° F. and finishing at 240° F. In this process aqueous vapor and the lighter oils are driven off. The "refined flux" is carried by steam-jacketed pipes to the mixing department, where it is used as a flux for treating asphaltum from the La Patera mine. This treatment consists of adding the refined flux to the crude asphaltum and revolving the mass in drums of 5 tons capacity and at a temperature of about 350° F. The amount of flux added depends on the degree of hardness required in the refined asphaltum. In about five hours the charge is run into a settling kettle, wherein the impurities settle, and from the bottom of which they are removed by a worm, and used as fuel. The refined asphaltum is conducted by a steam-jacketed pipe to the "barreling tank," from which it is drawn into a traveling kettle, running on an overhead gear and discharging the asphaltum into barrels. During all these processes the asphaltum is kept in a state of fluidity to admit of its being handled with celerity. The process of separating the maltha from the sand and refining the "crude flux" is a continuous one; the manufacture of the refined asphaltum is intermittent. The capacity of these works is 75 tons in twenty-four hours.

3.1.13. There is little doubt that the petroleum in the bituminous sand at the Las Conchas mine is derived from fissures in the Miocene shales; still there are no productive wells in the shales themselves. In 1894, Mr. P. C. Higgins, of Carpinteria, dug a 4'x6' well, 354' deep, at a point on the seashore about half a mile west of the Alcatraz refinery, which proved unproductive. The formation penetrated is a purple-colored bituminous shale, containing a few specimens of *Pecten peckhami*, and which bleaches almost white on exposure to the air. The dip of this shale is a little east of north. Eastward along the coast-line the exposed rocks are principally bleached shales, which at some places are much disturbed and contorted; and there are numerous faults. The prevailing dip is to the north, but in a few places the rocks dip southerly. This bleached shale is well exposed on the east side of Rincon Creek, at the base of Mount Hoar. As before mentioned, the bleaching of the shale appears to be due to solfataric action, or to some chemical process allied thereto. East of Carpinteria Creek, and for a distance of about 1 mile from the ocean, flowing water is obtained at less than 150' depth. In this area the formations penetrated by artesian wells consist of irregular strata of sand and clay. East of this artesian area the land surface rises, and the Miocene shale is struck about 30' in depth. Westward from Carpinteria, toward Serena, oil and water have been struck in shallow wells which penetrate the alluvial formations. This was the case on the Follinsbee ranch at Serena, about 100' north of the railroad track. Also, on the Cheeseborough ranch, adjoining the Follinsbee ranch on the south, oil and water were found at 25' depth. Also, on the Martin ranch, in a well about 1,000' southwest of the well on the Follinsbee ranch, oil and water were struck at 100' depth. It is said that at low tide an oil-spring is exposed on the seashore about a quarter of a mile southwest of the Martin ranch.

3.1.14. It is about a mile from Serena to Loon Point, near the Ortega railroad depot, where the Fischer oil-wells are situated, as hereinafter mentioned. At Loon Point strata of sandstone and conglomerate dip east of south at an angle of about 50°. It is rather more than a mile from Loon Point to Ortega Hill, where the first oil-well was drilled in the Summerland oil-field by Mr. Williams, in 1887. (See our VIIth Report, p. 90.) At Ortega Hill strata of sandstone and conglomerate dip S. 10° W., at an angle of between 60° and 70°. Resting non-conformably on these rocks is a recent formation, which dips northeasterly at an angle of less than 30°. This recent formation consists of very friable sandstones and gravelly strata; one stratum contains numerous shells, and the lowermost strata are bituminous. This recent formation can be traced from the seashore to the railroad cut on the southern slope of Ortega Hill, where it terminates. Northward from the seashore the land rises in rolling hills, which attain more than 300′ altitude in a distance of less than half a mile. The prevailing rocks in these hills are light-colored sandstones, whitish shales, and calcareous strata. On the southern slope of the first tier of hills, a dark-colored clay-shale is met, which constitutes the lowermost formation which comes to the surface on the south slope of the anticline on which the Summerland oil-wells are situated. This shale can be observed in a tunnel run for water. At that point the rock exposure is rather poor, but the dark-colored shales evidently dip southeasterly at a great angle. Farther northward a northerly dip is seen, and Messrs. Darling & Turner state that while drilling their well they observed that when a hard stratum was struck, the drill had a strong tendency to slide toward the north. The surface of the hills to the north of Summerland is covered with alluvium, principally adobe soil, and the few rocks which are exposed show numerous cracks and cross-fractures. It is probable that the underlying rocks are also fissured, and for the following reasons: As previously mentioned, we find at the shore-line, strata of sandstone and conglomerate dipping to the southeast at an angle of about 60°, while overlying strata of recent formation dip to the northeast at an angle of about 30°. Two distinct earth movements are thus indicated. First, one in which the rocks were inclined at a great angle toward the southwest, and later an earth movement of less magnitude, in which the rocks were bent nearly in an opposite direction. This, together with the closeness of the folds, fully accounts for all the crushing and cross-fractures observed. From the disposition of the more recent strata it appears that considerable erosion must have taken place during the interval between the two periods of disturbance. The territory in which productive wells have been obtained in Summerland extends along the seashore in an easterly direction from Ortega Hill. An examination of the outcropping rocks at Ortega Hill, and a comparison of the depth at which the oil-sand has been struck in different wells, demonstrate that the oil-yielding formations dip a little west of south at a great angle. These formations constitute a portion of an anticlinal fold, the axis of which extends along the crest of the first tier of hills which rises north of Summerland. The formation penetrated by the oil-wells consists of strata of sand or soft sandstone and blue clay, or clay-shale. The oil is contained in the sand or sandstone, and in some wells it has been observed issuing from crevices in

the clay or clay-shale. In all the productive wells north of the railroad the oil-sand has been struck at 80′ to 100′ depth. South of the railroad the oil-sand lies deeper, except at the Williams wells, on the seashore, where oil-soaked sand is found close to the surface. The Summerland oil which has hitherto been placed on the market has been black, or dark-green, and of 10° to 15° B. In a few instances oil of a much less specific gravity has been reported. An inspection of the oil-fields shows that there are no productive wells north of a line drawn N. 80° W. and S. 80° E. through the most eastern of the Doulton & Wilson wells. Such a line in a general way corresponds to the strike of the oil-yielding formation. If it were extended westward it would pass a little south of the old 455′ well of Mr. Williams, at the summit of Ortega Hill. There is a reasonable probability, therefore, of obtaining productive wells between this line and the ocean, and the wells drilled by Mr. Fischer at Loon Point show that the oil-yielding formations extend eastward from Summerland for more than a mile. It is also evident that the oil-yielding formations extend south into the ocean, for not only are productive oil-yielding strata penetrated by the Fischer wells, but at low tide springs of oil and gas are uncovered on the seashore. North of the line mentioned there are comparatively shallow wells, from which gas is obtained and used in Summerland for heating purposes. The formations underlying the strata pierced by the oil-wells appear to be principally dark-colored shales. These are penetrated in a 1,000′ well drilled by Williams & Easton, about 2,000′ northeast of the railroad depot, and a short distance south of the axis of the fold on which the Summerland oil-wells are situated. Mr. Williams states that the formation is grayish or reddish shale, and blue clay, and that at a depth of 1,000′ the red shale was saturated with oil. A 520′ well was drilled by Darling & Turner on the ridge about one quarter mile north of the railroad depot, and at about 200′ altitude. It is probable that this well is a little north of the axis of the fold on which the oil-wells are situated. Mr. Darling states that shale and sandstone were penetrated, and that some of the strata showed traces of oil.

3.1.15. *Alameda and Santa Barbara Development Co.'s Wells*, three in number, north of the railroad, are from 165′ to 172′ deep, and each yields 5 bbls. in twenty-four hours; also, two wells south of the railroad, 195′ and 210′ deep. Each of the two last-mentioned wells yields 8 bbls. in twenty-four hours.

3.1.16. *Backus & Cravens Wells.* These two wells are north of the railroad at Summerland, and are 100′ to 102′ deep. In 1895 they produced 332 bbls. of oil. Oil-sand struck at 70′ depth.

3.1.17. *Cole Well.* It is a dug well, 4′ in diameter and 90′ deep; it lies north of the railroad, and yields 3 bbls. of oil in twenty-four hours.

3.1.18. *Dewlaney Wells.* These three wells are north of the railroad at Summerland, and are 4½″ in diameter and 97′ to 123′ deep. The yield is 5 to 6 bbls. per twenty-four hours.

3.1.19. *Doulton & Wilson Wells.* These twelve wells, north of the railroad, are 4½″ to 5⅝″ in diameter, and were 100′ to 150′ deep when first drilled. In 1895 they yielded 10 bbls. each in twenty-four hours, but in July, 1896, only yielded 6 bbls. each. The four wells south of the railroad are 168′ to 175′ deep, and each yields 8 bbls. of oil in twenty-four hours.

3.1.20. *Fischer Wells.* These two wells are at Loon Point, and about 1 mile east of Summerland. One of them, a dug well on the seashore, is 124′ deep. Its oil is dark green and rather heavy. The other well is situated on Loon Point, about 80′ above the ocean. In August, 1895, this well was 185′ deep, and drilling was still in progress.

3.1.21. *Forester & Treadwell Wells.* These ten wells are south of the railroad at Summerland, and are 186′ to 222′ deep. Each yielded 5 bbls. in twenty-four hours.

3.1.22. *Loomis Wells.* These three wells are north of the railroad at Summerland, and are 140′ deep. Each yields 5 bbls. in twenty-four hours.

3.1.23. *Moore Wells.* These four wells are south of the railroad at Summerland, and are 206′ to 240′ deep. Each yields 7 bbls. in twenty-four hours.

3.1.24. *Stevens & Roberts Wells.* These three 4½″ wells are north of the railroad at Summerland, and are 130′ deep. Each yields 7 bbls. in twenty-four hours.

3.1.25. *Williams Wells.* Some years ago (see our VIIth Report, pp. 89 and 90), a 455′ well was sunk on Ortega Hill, but abandoned. Mr. Williams has six wells on the seashore; one, a 4½′x 5½′ dug well, is 50′ deep and yields 10 bbls. in twenty-four hours; one, a 4′x 5′ dug well, is 50′ deep and yields 3 bbls. in twenty-four hours. One well, dug 60′, and drilled to a total depth of 77′, and cased with 9⅝″ casing, may be made to yield, the owner says, 100 bbls. in twenty-four hours. One 57′ well, 12″ casing, yields 10 bbls. in twenty-four hours; and one 61′ dug well has yielded several hundred barrels of oil by bailing. Mr. Williams states that in two of his wells which are the farthest north, the oil is obtained in sandy strata, but that in the remainder of his wells the oil-yielding stratum consists of blue clay or clay-shale. He also states that in the dug wells this clay or clay-shale was found to be traversed by numerous crevices through which the oil oozes, and that the dip of these crevices is southwesterly.

3.1.26. The general character of the formation penetrated by the oil-wells north of the railroad at Summerland is:

Earth, cobblestones, and gravel	10′ to 25′
Blue clay	70′ to 120′
Oil-sand	undetermined.

South of the railroad track the general character of the formation is said to be:

Fine sand	10′ to 20′
Sand and cobblestones	5′ to 10′
Sand, with clay and some gravel	150′ to 170′
Oil-sand	40′

3.1.27. In some of the wells south of the railroad water has been struck about 220′ depth. In many of the wells sand is pumped up with the oil, and the oil is run into a "sand-box," where a large portion of the sand settles. This "sand-box" is a wooden trough divided by four upright partitions, which run across it. At the top of the partitions are notches through which the oil passes, and the sand is deposited at the bottom. The oil is run into a tank, at the bottom of which a 10″ space is allowed for any sand to settle which may still be in it.

3.1.28. In Summerland there are several wells which supply gas for fuel to the residents. The most remarkable feature about them is the

pressure of the gas at comparatively shallow depths. Thus, in a 104′ well, at times the pressure was so great that mud and dirt were thrown from the well 40′ or more into the air. (See our Xth Report, p. 601.) The rate at which the pressure has decreased can be gathered from the records of the following wells:

3.1.29. *The Cone Gas-Wells.* There are three 2½″ wells. Two are about 100′ northwest of the Doulton No. 2 well, and the other is situated about 50′ farther southwest. In the first two of these wells gas was struck at 100′, and in the last-mentioned, oil-sand was reached at 125′ depth. It is stated that when these wells were first drilled they supplied twenty families with fuel. In 1895 there was only sufficient gas for three families.

3.1.30. *The Darling Bros. Gas-Wells.* These two 2″ wells are situated about 1,200′ northwest of the Summerland railroad depot. The formation penetrated is:

Blue and yellow clay	99′
Hard limestone	100′
Sand, with gas to bottom of well	102′

The first well was drilled in 1891, and when completed the gas showed a pressure of 8 lbs. to the square inch; for one year it supplied seventeen families with fuel; the pressure gradually diminished, and in 1895 it was only 1 lb. to the square inch. The second well was completed in 1892, and has a similar record. In August, 1895, these two wells supplied ten families with fuel. It is stated that during a north wind these wells yield a strong flow of gas, but when the wind ceases the gas ceases to flow and a current of air is drawn down the well for several hours. In one instance, the latter phenomenon was noticed to continue for two days before inflammable gas again flowed from the well. There are several other wells in Summerland which yield enough gas to furnish one or more families with fuel.

OIL-WELLS NEAR SUMMERLAND.

3.1.31. *The Occidental Oil-Wells* are in the Santa Ynez Mountains, and about 5 miles northeast of Summerland. The formation penetrated (Fig. 35) is hard sandstone and dark-colored shale, probably of Eocene age. They consist of six wells, which are 200′ to 1,000′ deep. In all of them much water was encountered. In August, 1895, only one was being pumped, which is said to yield a few barrels of oil a day.

3.1.32. *Santa Monica Oil Co.'s Well* is on the edge of the Santa Ynez Mountains, about 2 miles north of Carpinteria, and is 700′ deep. (See Fig. 35.) It is said that amber-colored oil of 18° B. was struck at a depth of 400′, and that the yield was 8 bbls. in twenty-four hours; also, that when the well was deepened to 700′, flowing water was encountered, which "drowned out" the oil. The formation is hard sandstone of Eocene age, which dips S. 10° W. at an angle of 60°.

3.1.33. STATISTICAL REPORT OF SUMMERLAND OIL-WELLS FOR 1895.

Name of Producer.	Number of Wells.	Production in 1895.
		Bbls.
Alameda Development Co.	3	500
Backus & Craven	2	332
Cole, S. C.	1	175
Dewlaney, G.	3	400
Doulton & Wilson	8	3,316
Loomis, C. A.	3	3,000
Occidental	1	500
Stevens & Roberts	3	581
Williams, H. L.	4	8,100
Total	28	16,904

3.1.34. From the foregoing, it appears that the petroleum-yielding formations in the region herein described are as follows:

(*a*) Eocene formations, which correspond to the Eocene formations noted in the Sespe district and elsewhere in Ventura County. There is but little doubt that strata belonging to this formation are penetrated by the Occidental wells and the well of the Santa Monica Oil Co. The southern slope of the Santa Ynez Mountains between Rincon Creek and the Occidental oil-wells appears largely to be formed of rocks belonging to this age in which numerous springs of petroleum are found.

(*b*) Bituminous Miocene shales, which bleach on exposure and correspond to the bleached shales of the Sulphur Mountains and elsewhere in Ventura County. In Santa Barbara County there are no productive wells in these shales, but there is much bituminous matter distributed through them, and they constitute the wall rock of the Punta Gorda asphalt mine.

(*c*) Pliocene and Quaternary formations, containing secondary deposits of petroleum in the form of asphaltum and bituminous sand. The former class of deposits is represented by the Rincon asphalt mine, and the latter by the Las Conchas mine of bituminous sand.

(*d*) The Summerland oil-yielding formations. As yet no fossils have been obtained from the oil-yielding formations at Summerland, and there is not sufficient stratigraphic evidence to determine the geological horizon of the oil-yielding strata which are penetrated by the Summerland oil-wells.

CHAPTER II.

Summary.

3.2.01. This bulletin is designed to place in tangible form the historical and statistical facts relating to the petroleum industry in the portions of California of which it treats; also, to describe, as far as possible, the geological horizon of the petroleum-bearing rocks, and the structural conditions under which valuable deposits of petroleum have accumulated in the territory under discussion.

3.2.02. Although at this writing only a portion of the necessary evidence has been obtained, it is in order to see how far the work done elucidates the problem undertaken.

3.2.03. First, as to geological horizon. At Los Angeles, all the evi-

dence secured indicates that oil-bearing strata penetrated by the wells at Second-Street Park are of Pliocene age. The fact that in California Pliocene formations have been observed resting non-conformably on Miocene rocks, and that the Miocene has heretofore been assumed by many to be exclusively the geological horizon of the petroleum-yielding rocks of California, suggests that the oil-wells referred to have penetrated Pliocene strata and reached oil-bearing sands of Miocene age. The latter conclusion is not borne out by the evidence in sight.

3.2.04. At the Puente oil-field, the character and position of the exposed rocks indicate that the oil-yielding strata penetrated by the Puente oil-wells are much older than the Pliocene formations observed at the base of the Puente Hills. In Brea Cañon, the Pliocene formations rest apparently somewhat non-conformably on oil-yielding strata, from which what is regarded as a characteristic Miocene fossil was obtained.

3.2.05. In Ventura County the rock exposures are very much more satisfactory than at Los Angeles, or in the Puente Hills. In the Sespe district the petroleum-yielding rocks belong to two different geological horizons. As hereinbefore shown, the formation representing the uppermost of these horizons consists mainly of dark-colored shales, traversed by thin strata of hard bituminous limestone and by sandstone. The fossils obtained from this formation demonstrate that it was deposited between the Eocene and Miocene periods, and may be classified as Oligocene. This transition formation is penetrated by the oil-wells at Tar Creek, Four Forks, Brownstone or Los Angeles claim, and by the Kentuck wells. The rocks penetrated by the oil-wells at the southern base of the Sulphur Mountains may tentatively be referred to the same geological horizon, and it is probable that the oil of the Silverthread district has its source in rocks of this age.

3.2.06. The second, or lower oil-yielding horizon is distinctively of Eocene age (heretofore classed as Cretaceous B). It is separated from the upper oil-yielding horizon by rocks which are several thousand feet in thickness. The rocks comprising this horizon consist of hard sandstones, a little conglomerate, and dark-colored shale. Most of these distinctively Eocene formations, which the writer has observed in Ventura County, show more or less evidence of metamorphism. These Eocene rocks can be traced westward from the Sespe district to the Santa Ynez Mountains, in Ventura County. In many places springs of heavy petroleum issue from them. The California Oil Co.'s well in the Sespe district, and two 250′ wells in Echo Falls Cañon north of the Silverthread oil district, penetrate the hard Eocene sandstones. It is said that these wells were drilled with a spring pole, and that they yielded heavy oil and sulphureted water.

3.2.07. In the Santa Ynez Mountains, in Santa Barbara County, the Eocene formations are penetrated by the Santa Monica oil-well near Carpinteria, and there is every reason to suppose that the rocks penetrated by the Occidental oil-wells are of this age, although the writer obtained no fossils from the rocks exposed at the last-mentioned wells.

3.2.08. As previously stated, sufficient evidence has not been obtained to determine the geological horizon of the oil-yielding formation at Summerland, in Santa Barbara County.

3.2.09. The evidence thus far obtained warrants the conclusion that the oil-yielding formations in the districts described in this bulletin belong respectively to the following geological horizons:

Name of Oil Field.	Geological Horizon of Oil-yielding Rocks.
Second-Street Park wells, at Los Angeles	Pliocene.
Puente wells	Older than Pliocene; exact age undetermined.
Brea Cañon, in Puente Hills	Miocene.
Upper oil-yielding formations of the Sespe District.	Oligocene (*i. e.* transition between Eocene and Miocene.)
O'Hara wells and the oil-yielding formations on south side of Sulphur Mountains	Probably Oligocene.
Silverthread wells	Probably Oligocene.
Lower oil-yielding horizon, Sespe District	Eocene.
Santa Monica wells, Santa Barbara County	Eocene.
Occidental wells	Probably Eocene.
Summerland wells	Undetermined.

3.2.10. The following definitions will explain to those who are unfamiliar with the subject under discussion, why emphasis is laid on the geological horizon of the different oil-yielding formations: Petroleum deposits are divided into two classes, namely, primary and secondary deposits:

(*a*) The primary deposit is contained by the rocks in which the petroleum was formed, or originally accumulated;

(*b*) The secondary deposit is formed where petroleum wanders from the strata in which it originally accumulated, and finds a resting-place in other rocks under conditions which are favorable to its storage.

3.2.11. Primary deposits, in various parts of the world, have been found to belong to definite geological horizons. Careful investigation has shown that the oil-yielding strata of which these primary deposits consist have a definite position in the geological horizon to which they belong; and frequently the oil-yielding rocks can be traced from fold to fold and mountain to mountain, wherever the characteristic rocks representing their geological horizon are exposed.

3.2.12. The secondary deposits are, in the nature of their occurrence, erratic and local. As before mentioned, they consist of rocks saturated with petroleum, which, by means of fissures or other channels, has found its way from some primary deposit.

3.2.13. In some cases it is difficult to distinguish the primary from the secondary deposits; but when rocks belonging to a certain geological horizon are found to be oil-bearing, not only in one place, but on different folds and in different localities, it may safely be assumed that such oil-bearing rocks belong to a primary deposit of petroleum.

3.2.14. The evidence thus far gathered concerning the petroleum-yielding rocks of California leads to the following conclusions: First, that the Oligocene formations, previously referred to, contain a primary deposit of petroleum; that this deposit is found in the lower portion of a certain bed of dark-colored shales, and in certain strata of sandstone, interstratifying and immediately underlying the said shales; that the Eocene formations also contain primary deposits of petroleum. (At present there is only one productive well which derives its oil from this distinctively Eocene formation within the territory described in this bulletin.)

3.2.15. At this writing there is not sufficient evidence forthcoming to determine whether or no the Los Angeles and the Puente and the Summerland oil-wells penetrate primary or secondary deposits of petroleum. Portions of the slaty shale formation, which can be observed at the Sulphur Mountains, Carpinteria Bay, and elsewhere, and which exhibits

such a tendency to bleach on exposure, may be regarded as containing primary deposits of petroleum, but the petroleum is too diffused to be of value, except where it occurs as veins of asphaltum.

3.2.16. Examples of secondary deposits of petroleum are found in the deposits of asphaltum and bituminous sand which are described as occurring in formations which have a vertical range from Miocene to the Quaternary. The deposit of bituminous sand at the Las Conchas mine, in Santa Barbara County, is a typical example of a secondary deposit of petroleum.

3.2.17 A review of the territory under discussion shows that the deposits of petroleum described in this bulletin occur under the following structural conditions:

3.2.18. At Los Angeles the petroleum-yielding rocks form an oil-line far down the slope of what appears to be an illy defined anticlinal fold. There is no geological evidence in sight to show that this oil-line has any particular reference to the axis of any anticline; oil, and oil and water, have been found at intervals along this oil-line for a distance of more than five miles. At the Second-Street Park oil-field, probably owing to the effect of subordinate folds or flexures, conditions have been produced favorable to the accumulation of the oil. There are numerous faults in the rocks of this locality, but it does not appear that the throw of any of them is very great.

3.2.19. In the Puente oil-field the productive wells are situated on both slopes of an anticlinal fold. In Brea Cañon in the Puente Hills there is a line of oil-seepages along the axis of an anticlinal fold. In the Sespe district all the productive wells are near the axis of anticlinal folds, and at or near the termination of those folds.

3.2.20. The wells at the southern base of Sulphur Mountains—the O'Hara wells and the Silverthread wells—are also situated near the axis of anticlinal folds. At the Silverthread wells the stratigraphy is complicated by faults and fissures, and the rocks are crushed. At Summerland the oil-wells are at no great distance from the axis of an anticlinal fold. It is seen, therefore, that, in nearly all the instances observed, the anticlinal structure has presented the conditions under which the petroleum has accumulated.

3.2.21. As previously mentioned, the prevailing structure of the rocks in the territory under discussion is that of closely compressed anticlinal folds, and the compression has resulted in much crushing and fracturing of the rocky strata. These conditions favor the migration of petroleum and the formation of secondary deposits.

3.2.22. In this bulletin no attempt is made to force conclusions. When the evidence in sight is insufficient to warrant an expression of opinion, all that safely can be done is carefully to record such evidence as is forthcoming. In such case it is a reasonable presumption that eventually further evidence will be obtained, which, when coupled with that already secured, will be sufficient to warrant the formularization of deductions.

3.2.23. Those who are familiar with the researches made in the Eastern oil-fields well know that it has taken the combined efforts of many able men for years to collect and collate the data of the oil-yielding formations there, and it cannot be expected that similar work can be done as rapidly by a few in California, where the geology is much more complicated than it is in the Eastern oil-fields.

FIG. 26. ST. LOUIS RIG.

FIG. 27. STAR RIG.

FIG 28. STANDARD RIG.

PART IV.

MISCELLANEOUS.

CHAPTER I.

Refineries in Los Angeles and Ventura Counties.

4.1.01. *Asphaltum and Oil-Refining Co.* The plant on Santa Fe R. R. Avenue and Ninth Street, Los Angeles, consists of four stills: two of 125 bbls. each, one of 50 bbls., and one of 30 bbls. capacity. The production is lubricating oil, asphaltum, and distillate which is used for fuel.

4.1.02. *Clark, Johns & Co.* Their oil-works are located at Ventura. The plant consists of two stills and one retort, with a total capacity of 60 bbls. per twenty-four hours. The product is illuminating and lubricating oils and asphaltum.

4.1.03. *Oil-Burning Supply Co.* Its plant, at the corner of Date Street and Alhambra Avenue, consists of three stills of 100 bbls. capacity each, and storage tanks of total capacity of 5,000 bbls. The product is distillate for fuel, asphalt of A, B, C, and D grades, and liquid asphaltum, used for fluxing asphaltum which is used for roofing.

4.1.04. *Puente Oil Co.'s Refinery.* It is at Chino, San Bernardino County, and has a capacity of 200 bbls. of refined petroleum a day. The refined product consists of illuminating oil of 120° fire test, gasoline 72° B., benzine 58° B., and the residues, which are sold as fuel.

4.1.05. *The Union Oil Co.* has removed its refinery from Santa Paula to Oleum, on San Pablo Bay, in Contra Costa County, where it has erected a new refinery, which has a capacity of 12,000 bbls. a month. Product: gasoline, naphtha, illuminating oil, and asphaltum.

CHAPTER II.

Drilling Machinery Used in Los Angeles.

4.2.01. When the Los Angeles oil-field was first devéloped, horse-power and hydraulic rigs were used. These soon gave place to the St. Louis, the Star, and the Standard rigs.

4.2.02. *The St. Louis Rig* (Fig. 26) consists of a wagon frame which carries the rig, upright boiler, double-cylinder engine, and grasshopper walking-beam; a $1\frac{3}{4}''$ cable is used, and the tools are lighter than those used with the Star and the Standard rigs. This rig is suitable for wells not exceeding 600′ in depth.

4.2.03. *The Star Rig* (Fig. 27) resembles the Standard, except that the Star is portable; it has a Sampson-post and walking-beam. The

sand reel is driven by friction with the inside of the band wheel, and the band wheel is 76″ in diameter. The bull-wheel shaft is of iron with iron flanges, and is situated directly back of the Sampson-post, and is driven by a draw belt. The rig is furnished with T boiler of 18 H.P. and an 8″ x 8″ single-cylinder engine. It is provided with a 44′ mast and a 34″ crown pulley, which can be used instead of a derrick. The tools are much heavier than those used with the St. Louis rig; the stem is 26′ x 3½″. The Star rig is suitable for drilling to a depth of 800′.

4.2.04. *The Standard Rig* (Fig. 28), now universally used in the Los Angeles field, is so well known that minute description is not required. At first an 8′ band wheel and a 12 H.P. engine were considered sufficient, but as wells increased in depth, the diameter of the band wheel was increased to 9′ and a 15 H.P. engine employed. The bull wheels are 7′ to 7½′ in diameter. A straight sand reel is used on account of the excessive amount of sand-pumping required. The frictional pulley on the sand reel is at least 34″ in diameter. The derricks are usually about 56′ high, with a 16′ base. The walking-beam is about 22′ in length, and 3½″ rig-irons are used. The timbers for the sills and Sampson-post are 12″x12″, usually. A 2″ or 2⅛″ cable, and a 1⅛″ to 1¼″, hard-laid sand line are used. The stems vary from 22′ to 30′ in length, and from 3½″ to 4″ in diameter. Horizontal tubular or firebox boilers of 20 to 35 H.P. are employed. The Standard rig is suitable for drilling the deepest wells, but for drilling below a depth of 1,500′ a heavier set of tools is needed than those herein mentioned.

4.2.05. It is said that the actual expense of drilling in the Los Angeles oil-field has been about 50 cents per foot, and that many contracts have been taken at $1 per foot for wells of less than 1,000′ in depth.

4.2.06. The diameters of the casings usually used are 4¼″, 4¼″, 4¾″, 5″, 5⅝″, 6⅝″, 8⅝″, and 9⅝″. In screw casing the most popular sizes are 5⅝″ and 7⅝″.

4.2.07. During 1895, the cost per foot of casing at Los Angeles was, for 5⅝″, 40 cents; for 6⅝″, 50 cents; for 7⅝″, 66 cents; for 8⅝″, 80 cents; and for 9⅝″, $1. A steel shoe is used at the bottom of the casing, to protect it during the process of driving. The driving is done from the top.

4.2.08. The price of labor in the Los Angeles oil-field during 1895 was: Drillers, $4 to $5; tool-dressers, $2 50 to $3 50; and laborers, $1 50 to $2 per day.

4.2.09. Two-inch iron tubing is used for the pumps, and ½″ black iron pipe or acme iron rods for the sucker rods. Wooden rods are not used at Los Angeles, on account of the great specific gravity of the oil. A common working-barrel and working-valves with leather cups are in ordinary use, but in wells where the sand gives much trouble, a Snow working-barrel or a working-barrel with a solid plunger is employed.

4.2.10. *Allen's Patent Pumping Rig* (see Fig. 29) is in general use, and sometimes twenty wells are pumped from one station. Allen's patent rig consists of a vertical shaft driven by a bevel-gear; upon the upper end of the shaft is an eccentric to which are attached the wires or pitmans from the various pumps, preferably in such manner that the pull of the pumps will balance one another. When this cannot be attained, a counter-balance is employed. The stroke of the pump corresponds to the revolution of the eccentric, being twelve to seventeen

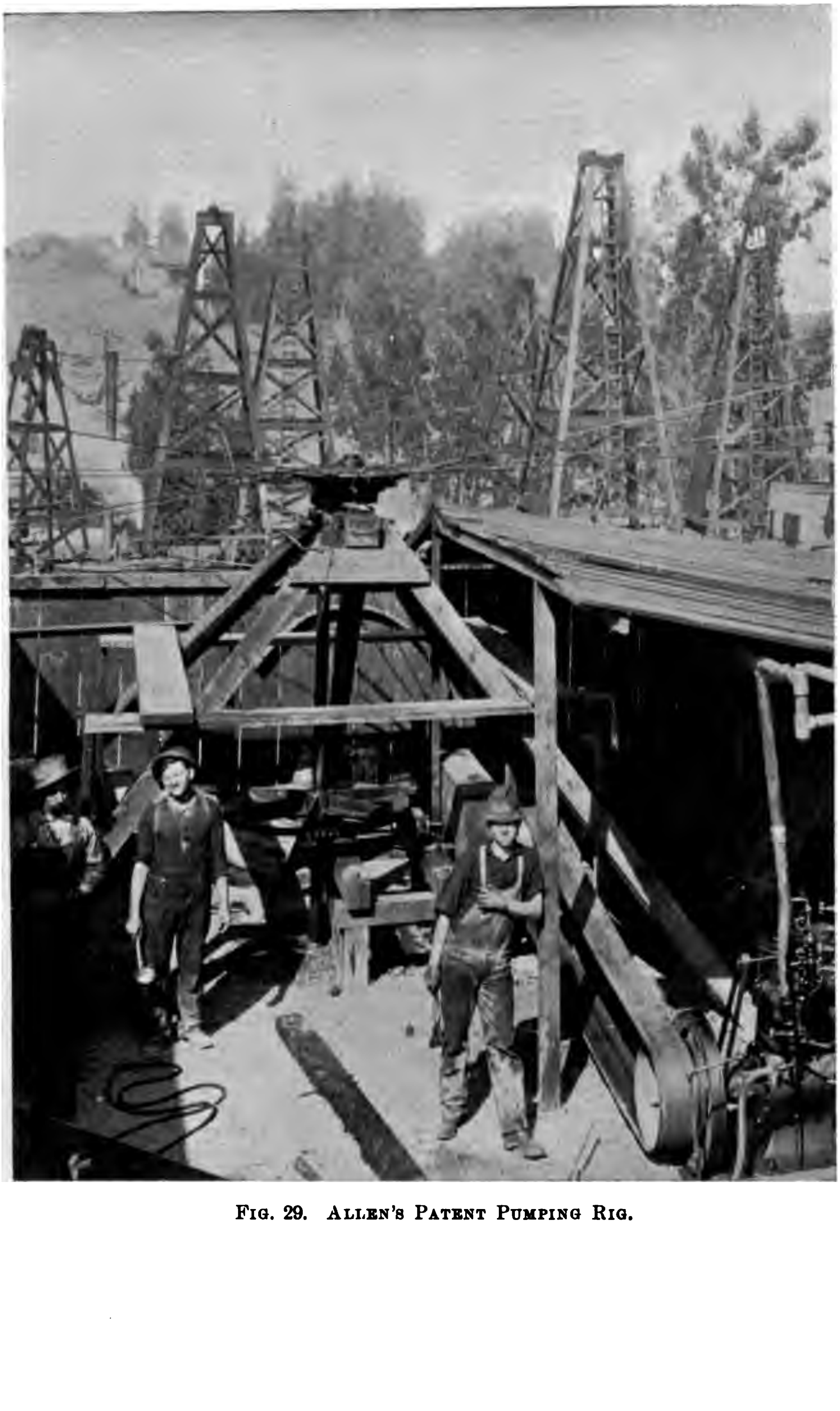


FIG. 29. ALLEN'S PATENT PUMPING RIG.

strokes a minute, according to the gravity of the oil and the amount of oil pumped at each stroke. When the wells are a great distance apart, connection is made by wire cables to a reciprocating jack. In some oil-fields the power is conveyed by this means for more than half a mile.

4.2.11. Steam and, in a few instances, gas engines furnish the motive power. Oil is the usual fuel, and natural gas is used to a limited extent.

CHAPTER III.

Oil as Fuel in Los Angeles County, and Calorimetric Tests.

4.3.01. Oil is largely used for fuel on the Southern California Railway, a portion of the Santa Fe system, between Barstow and San Diego. More than half of their locomotives are now adapted to the use of oil as fuel. The burners used were invented by W. Booth, formerly master mechanic of the Central Railroad of Peru, and the Santa Fe Company have made some improvements in the original design. Experiments, extending over a period of six months, demonstrated the superiority of oil as compared with solid fuel. An average of the results obtained show that 4 bbls. of oil did the same work as 2,200 lbs. of Nanaimo coal. Experiments extending over sixteen days, with a freight engine, 19"x 28" cylinders, gave an average evaporation of 13.11 lbs. of water to each pound of coal consumed. Taking coal at $6 65 per 2,000 lbs., and oil at $1 33 per barrel, a money saving of 27.1% is effected. The oil used in this experiment was supplied by the Union Oil Company, and its specific gravity was 23° B. During January, 1896, oil was used as fuel on twenty-five locomotives, being equally divided between passenger and freight service. The results showed:

Oil consumed by these twenty-five locomotives during January	2,077 tons.
Distance traveled	87,063 miles.
Average cost per mile	14.39 cents.

4.3.02. The gravity of the oil used was 15° B. During January, 1896, coal was used as fuel on twenty-five locomotives. They performed practically similar work to the engines fired by oil: Average cost per mile, 23.20 cents, or practically a money saving of 37.975% in favor of oil.

4.3.03. During January, 1896, the cost of coal was $6 60 per 2,000 lbs. During January, 1896, the cost of oil was $6 03 per 2,000 lbs. During December, 1895, an overland passenger engine, cylinders 19"x 26", ran 7,347 miles and consumed 143.2 tons of oil. A similar service with coal required 294 tons. Taking oil at $6 03 per 2,000 lbs. and coal at $6 60 per 2,000 lbs., the relative value shows:

Cost of oil	$863 50, or 11.75 cents per mile.
Cost of coal	$1,940 40, or 26.41 cents per mile.

Practically a money saving of 55.5%. The average of other experiments made with oil as fuel was 14.24 cents per mile. In these experiments steam from the boiler was used to atomize the oil and the oil is heated by a steam coil to a temperature of 100° to 120° F. Two 4" flat-mouthed burners are used to each engine. The fire-box is protected with fire-brick, and there is an arch of fire-brick at the back of the flues, similar to that in coal-burning locomotives. The Los Angeles Consolidated Electric Railway Company made a series of careful experiments to test

the value of Puente oil as compared with Wellington coal. The results of tests on runs, which averaged nineteen hours per day for ten days, showed that 19.41 tons of Wellington coal had a fuel value equal to that of 2,957 gals. of oil, specific gravity 24° B. The use of oil also saved the labor of five men at $2 a day each. In two of the power-houses the Wilgus steam burner is used, and in one the Gilbert & Barker aërated burner. It is said that these burners give practically the same results. Oil is used as fuel in the rolling-mills of the Los Angeles Steel and Iron Company. The Crawford and the Wilgus burners are employed, in which the oil is atomized by steam. The superintendent of this company states that it requires about 1⅝ bbls. of oil to manufacture a long ton of muck bar from scrap iron, and about the same amount of oil to manufacture the muck bar into finished sheet iron. Thus, it takes about 3¼ bbls. of oil to manufacture one ton of finished sheet iron from scrap. He also states that, for steam purposes, 3 bbls. of oil equal 2,000 lbs. of good bituminous coal; and that, for the heating furnaces, 2½ bbls. of oil equal 2,000 lbs. of bituminous coal; thus, taking coal at $6 65 per ton of 2,000 lbs. and oil at $1 per barrel, the use of oil instead of coal at these works effects a saving, in round figures, of 54.6% for steam purposes, and 62.5% for the heating furnaces.

4.3.04. The court-house at Los Angeles is heated by steam furnished by two boilers of 75 H.P. estimated capacity. Crude oil of specific gravity 22° to 26° B. is used in Gilbert & Barker aërated burners for fuel. In these burners the oil is atomized by air. The engineer states that when the boilers are running at their full capacity 1 gal. of oil will evaporate 15 gals. of water; *i. e.*, practically 1 lb. of oil will evaporate 15 lbs. of water; also, that 1 lb. of good coal would evaporate about 8 lbs. of water in these boilers.

4.3.05. The Los Angeles Pressed Brick and Terra Cotta Company have five kilns whose capacity ranges from 20,000 to 40,000 brick. They use oil as fuel. The manager states that they have tried both steam and air burners, and have concluded that the air burner is the best, on account of its introducing less moisture into the kiln. That estimating good bituminous coal at $8 per ton, and oil of 30° B. at $1 40 per barrel, the use of oil effects a saving of about 15% in the fuel and also the labor of one man to each kiln.

4.3.06. At the California Sewer Pipe Works, at Vernon, there are three 20′ and two 28′ down-shaft kilns. DeBow steam burners are used. The manager states that the work done with $85 worth of coal, at $7 75 per ton, can be done with $30 worth of oil at 60 cents per barrel. Oil is being used as fuel for open brick kilns by several of the brick manufacturers at Los Angeles. It is said that 1 bbl. of oil is sufficient to burn 1,000 brick, and is therefore equal to ¼ cord of good wood. The price of wood is $6 a cord.

4.3.07. From the foregoing, the relative fuel value of coal and oil shows:

L. A. S. & I. Co., heating furnaces	1 ton Wellington coal = 2.50 bbls. of oil.
L. A. S. & I. Co., steam purposes	1 ton Wellington coal = 3.00 bbls. of oil.
L. A. Con. Electric Railway Co.	1 ton Wellington coal = 3.62 bbls. of oil.
L. A. Court-House, steam purposes	1 ton good coal = 3.10 bbls. of oil.
So. Cal. Ry. Co.	1 ton Nanaimo coal = 4.00 bbls. of oil.

Those who have experimented with oils of different specific gravity state that they find very little difference in the actual fuel value of the

oil tested, but that oil of a high specific gravity requires to be heated in order that it may pass freely through the feed pipes and be readily atomized; moreover, oils of high specific gravity usually contain water and earthy matter.

4.3.08. In 1895 there was a prevailing opinion that the oils of high specific gravity had a much less fuel value than the oils of low specific gravity. To determine this point experiments were conducted in the laboratory of the State Mining Bureau. Samples of oil varying from 13° B. to 34° B. were burned in oxygen beneath a calorimeter, which had been calibrated with hydrogen, as described in Bulletin No. 3. The samples of heavy oil were cut with gasoline and the calorific value of the gasoline deducted. The results showed a range of from 9,999 to 10,381 kilo-calories for the samples of oil tested. This was sufficient to demonstrate that there was no great difference in the relative calorific value of the samples tested, but limitations as to time prevented a sufficient number of experiments being made to work out the relative fuel values for the different specific gravities. The samples tested had been comparatively freed from water and earthy matter.

4.3.09. It is interesting to note how the laboratory tests compare with the practical use. Taking anthracite coal as a standard, one ton of which is equivalent to 8,092 kilo-calories (available heat units) per kilogramme. Comparative working tests have shown that an average sample of Nanaimo coal has an available fuel value of 6,684 kilo-calories per kilogramme. Calorimetric tests made in the laboratory of the State Mining Bureau showed that a sample of Los Angeles oil of 0.973 specific gravity (equal to 13° B.) had an available fuel value of 10,203 kilo-calories per kilogramme. Practical work on the Southern California Railway showed that 4 bbls. of petroleum 15° B. (or 1,352 lbs.) have a fuel value of $1\frac{1}{10}$ tons of Nanaimo coal. As $1\frac{1}{10}$ tons of Nanaimo coal is equivalent to 6,683,332 kilo-calories, therefore, 1 ton of petroleum of 15° B. (2,000 lbs.) has a working equivalent to 9,886,585 kilo-calories.

4.3.10. RELATIVE FUEL VALUE.

	Available "Heat Units" in One Kilogramme.	Available "Heat Units" in One Ton, Calculated as 909 Kilogrammes.
Nanaimo coal	6,684	6,075,756
Sample of Los Angeles oil, 13° B., calorimetric test in laboratory of State Mining Bureau	10,203	9,274,527
Sample of petroleum, 15° B., from practical working test on So. Cal. Ry. as compared with Nanaimo coal		9,886,585

4.3.11. From the foregoing, the following ratios of fuel value have been computed: Assuming that 1 lb. of coal is equal to 1 heat unit, 1 lb. of oil, per Mining Bureau tests, is equivalent to 1.526 heat units; 1 lb. of oil, per So. Cal. Ry. Co.'s tests, is equivalent to 1.629 heat units.

4.3.12. In a furnace a more complete combustion can be secured with petroleum than it is possible to obtain with coal. Therefore, it is not surprising to find that practical work on the Southern California Railway gave a somewhat higher fuel value to the petroleum than did the calorimetric tests in the laboratory. Moreover, the samples of petroleum used in the laboratory and on the railway were dissimilar.

4.3.13. The following tests on the relative fuel value of petroleum were made by Prof. H. Stillman, in the laboratory of the Southern Pacific Company, at Sacramento. The calorific value was determined by Thompson's calorimeter, and represents theoretical pounds of water evaporated at and from 212° F. by one pound of fuel.

Calorimetric Experiments with Oil.

	B.*	Water Evaporated.	Calorific Value, in Kilogramme "Heat Units."
Lubricating oil	24° to 25° B.	20.09 lbs.	10,788
Crude oil	16° to 17° B.	18.25 lbs.	9,800

Proximate Analysis and Calorimetric Experiments with Coal.

	Mount Diablo, Cal.		Amador County, Cal.			Colorado.
	Clark Vein.	Clark Vein.	Ione.	Carbon Hill.	Comax.	Carson.
Moisture	8.15%	11.55%	17.65%	6.30%	.90%	.90%
Volatile matter	38.24	37.59	43.30	26.30	28.08	29.00
Fixed carbon	37.24	36.59	23.00	50.70	54.38	38.23
Ash	11.45	9.05	15.85	16.00	12.50	23.70
Sulphur	4.95	5.22	----------	.70	4.14	8.14
Total	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%
Color of ash	Lt. Brwn.	Gray.	Brown.	Gray.	Gray	Purple.
Cooking quality	Poor.	Poor.	Poor.	Fair.	Fair.	Good.
Water evaporated by one pound of coal	11.28	12.01	9.65	12.9	13.52	12.06
Calorific value, in kilogramme "heat units"	6,057	6,449	5,175	6,927	726	6,476

CHAPTER IV.

Fractional Distillations.

.01. In order to determine the character of the oil yielded by the ent formations described in this bulletin, the samples of oil men- d in the following table were, by the writer, subjected to fractional lation in the laboratory of the State Mining Bureau. The tempera- given are those of the vapors in the head of the retort:

Sample was Obtained from—	Crude Oil.		Naphtha.		
	Specific Gravity	Nearest Corresponding Degree to Scale	Volumetric Percentage of Distillate cut off at 150° C.	Specific Gravity	Nearest Corresponding Degree to Scale
ngeles—					
nd-Street Park (*a*)	0.9534	17° B.	Traces.		
nd-Street Park (*b*)	0.9520	17° B.	Traces.		
nd-Street Park (*c*)	0.9515	17° B.	Traces.		
nd-Street Park (*d*)	0.9539	17° B.	Traces.		
nd-Street Park (*e*)	0.9528	17° B.	Traces.		
nd-Street Park (*f*)	0.9565	16° B.	Traces.		
nd-Street Park (*g*)	0.9580	16° B.	Traces.		
ntosh Well, West Los Angeles	0.9816	13° B.	Traces.		
an Well, West Los Angeles	0.9702	14° B.	Traces.		
erland (*a*)	0.9672	15° B.	Traces.		
erland (*b*)	0.9513	17° B.	Traces		
erland (*c*)	0.9657	15° B.	Traces.		
erland (*d*)	0.9672	15° B.	Traces.		
erland (*e*)	0.9692	15° B.	Traces.		
eek	0.9125	23° B.	7.6%	0.7350	60° B.
eek	0.9129	23° B.	8.4	0.7240	63° B.
'orks	0.9196	22° B.	Traces.		
ck	0.9015	25° B.	6.0	0.7200	64° B.
nia Oil Co.	0.9402	19° B.	Traces.		
hread Oil District (*a*)	0.9366	20° B.	5.0	0.7560	55° B.
hread Oil District (*b*)	0.9255	21° B.	7.0	0.7428	59° B.
hread Oil District (*c*)	0.9369	20° B.	Traces.		
hread Oil District (*d*)	0.9442	18° B.	Traces.		
hread Oil District (*e*)	0.9590	16° B.	Traces.		
a Wells	0.9435	18° B.	Traces.		
a Wells	0.9769	14° B.	Traces.		
& Gillmore	0.9302	20° B.	Traces.		
& Gillmore	0.9486	18° B.	Traces.		
ton Tunnel	0.9398	19° B.	Traces.		
ton Green Oil	0.9333	20° B.	Traces.		
Tunnel	0.9773	13° B.	Traces.		
e	0.9193	23° B.	Traces.		
e	0.8893	28° B.	10.2	0.7323	61° B.

FRACTIONAL DISTILLATIONS—Continued.

Sample was Obtained from—	Illuminating Oil.					
	Volumetric Percentage of Distillate cut off at 200° C.	Specific Gravity	Nearest Corresponding Degree to Scale.	Volumetric Percentage of Distillate cut off at 250° C.	Specific Gravity	Nearest Corresponding Degree to Scale.
Los Angeles—						
Second-Street Park (*a*)	Traces.			8.0%	0.8330	38° B.
Second-Street Park (*b*)	Traces.			7.0	0.8304	38° B.
Second-Street Park (*c*)	Traces.			6.4	0.8274	39° B.
Second-Street Park (*d*)	Traces.			9.6	0.8255	40° B.
Second-Street Park (*e*)	Traces.			8.0	0.8153	42° B.
Second-Street Park (*f*)	Traces.			1.6		
Second-Street Park (*g*)	Traces.			2.2		
Mackintosh Well, West Los Angeles	Traces.					
Maltman Well, West Los Angeles	Traces.			1.0		
Summerland (*a*)	Traces.			2.0		
Summerland (*b*)	Traces.			Traces.		
Summerland (*c*)	Traces.			Traces.		
Summerland (*d*)	Traces.			Traces.		
Summerland (*e*)	Traces.			Traces.		
Tar Creek	11.0%	0.7595	55° B.	10.4	0.8200	41° B.
Tar Creek	8.0	0.7430	58° B.	10.4	0.7985	45° B.
Four Forks	6.9	0.7684	52° B.	16.8	0.8005	45° B.
Kentuck	8.6	0.7600	54° B.	10.0	0.8047	44° B.
California Oil Co.	7.3	0.7640	53° B.	9.5	0.8012	45° B.
Silverthread Oil District (*a*)	7.6	0.7673	52° B.	8.0	0.7945	46° B.
Silverthread Oil District (*b*)	10.4	0.7614	54° B.	8.0	0.8001	45° B.
Silverthread Oil District (*c*)	10.0	0.7680	52° B.	14.6	0.8273	39° B.
Silverthread Oil District (*d*)	6.0	0.7556	55° B.	10.6	0.8010	45° B.
Silverthread Oil District (*e*)	Traces.			Traces.		
O'Hara Wells	5.6	0.7784	50° B.	6.4	0.8032	44° B.
O'Hara Wells	Traces.					
Scott & Gillmore	Traces.			12.0	0.8044	44° B.
Scott & Gillmore	Traces.			Traces.		
Pinkerton Tunnel	Traces.			9.6	0.8085	43° B.
Pinkerton Green Oil	Traces.			11.6	0.8015	45° B.
Magie Tunnel	Traces.					
Puente	15.9	0.7660	52° B.	10.8	0.8013	45° B.
Puente	13.5	0.7656	53° B.	12.2	0.8089	43° B.

FRACTIONAL DISTILLATIONS—Continued.

ple was Obtained from—	Illuminating Oil—Continued.			Lubricating Oil.		
	Volumetric Percentage of Distillate cut off at 300° C.	Specific Gravity	Nearest Corresponding Degree to Scale.	Volumetric Percentage of Distillate cut off at 350° C.	Specific Gravity	Nearest Corresponding Degree to Scale.
ngeles—						
›nd-Street Park (*a*)	13.6%	0.8653	32° B.	3.0%	----	----
›nd-Street Park (*b*)	15.3	0.8809	29° B.	7.1	0.8890	27° B.
›nd-Street Park (*c*)	16.8	0.8710	31° B.	8.0	0.8895	27° B.
›nd-Street Park (*d*)	17.6	0.8771	36° B.	5.0	0.8922	27° B.
›nd-Street Park (*e*)	12.0	0.8642	32° B.	4.0	----	----
›nd-Street Park (*f*)	11.4	0.8662	32° B.	3.4	----	----
›nd-Street Park (*g*)	11.2	0.8721	30° B.	7.0	0.8820	29° B.
ntosh Well, West Los ;eles	1.6	----	----	4.4	----	----
ıan Well, West Los ;eles	8 0	0.8680	31° B.	9.6	----	----
ıerland (*a*)	11.0	0.8452	36° B.	5.0	0.8722	30° B.
ıerland (*b*)	19.4	0.8550	34° B.	12.0	0.8962	26° B.
ıerland (*c*)	11.6	0.8468	36° B.	6.8	0.8900	27° B.
ıerland (*d*)	6.0	----	----	5.0	----	----
ıerland (*e*)	----	----	----	4.6	----	----
reek	12.4	0.8514	34° B.	6.0	0.8834	29° B.
reek	14.2	0.8602	33° B.	4.0	----	----
Forks	9.7	0.8369	38° B.	6.6	0.8604	33° B.
ıck	12.2	0.8450	36° B.	2.5	0.8662	32° B.
rnia Oil Co.	11.3	0.8502	34° B.	2.9	0.8608	33° B.
thread Oil District (*a*)	7.6	0.8403	36° B.	5.8	0.8746	30° B.
thread Oil District (*b*)	9.8	0.8430	36° B.	6.4	0.8612	33° B.
thread Oil District (*c*)	9.6	0.8478	37° B.	7.6	0.8791	29° B.
thread Oil District (*d*)	11.0	0.8525	34° B.	4.0	0.8790	29° B.
thread Oil District (*e*)	5.0	0.8500	35° B.	7.0	0.8780	29° B.
a Wells	14.4	0.8532	34° B.	6.0	0.8738	30° B.
a Wells	13.0	0.8530	34° B.	3.0	----	----
& Gillmore	16.0	0.8443	36° B.	3.2	----	----
& Gillmore	6.0	0.8465	35° B.	7.6	0.8603	33° B.
rton Tunnel	17.2	0.8500	35° B.	5.0	0.8701	31° B.
rton Green Oil	16.0	0.8406	37° B	5.0	0.8620	33° B.
Tunnel	----	----	----	16.0	0.8701	31° B.
e	9.3	0.8500	35° B.	2.9	0.8610	33° B.
e	10.2	0.8413	36° B.	8.3	0.8502	34° B.

4.4.02. The following samples of crude oil from districts referred to in this bulletin were subjected to fractional distillation in the laboratory of the State Mining Bureau by W. D. Johnston in 1887:

Locality from which Sample was Obtained.	Crude Oil.		Naphtha.					
	Specific Gravity	Nearest Corresponding Degree to Scale	Below 100° C.	Specific Gravity	Nearest Corresponding Degree to Scale	Below 125° C.	Specific Gravity	Nearest Corresponding Degree to Scale
Tar Creek	0.833	28° B.	10.0%	0.720	64° B.	6.8%	0.755	55° B.
Sespe No. 2	0.859	33° B.	9.1	0.700	70° B.	9.2	0.734	61° B.
Green Oil Well, Adams Cañon	0.853	34° B.	....	....	....	7.8	0.740	50° B.
Wild Bill, Adams Cañon	0.915	23° B.	....	....	....	....	....	....
Puente	0.822	28° B.	10.6	0.717	65° B.	8.7	0.747	57° B.

Locality from which Sample was Obtained.	Naphtha—Continued.			Illuminating Oils.		
	Below 150° C.	Specific Gravity	Nearest Corresponding Degree to Scale.	Below 200° C.	Specific Gravity	Nearest Corresponding Degree to Scale.
Tar Creek	5.5%	0.777	50° B.	9.7%	0.809	....
Sespe No. 2	8.8	0.762	54° B.	11.8	0.798	54° B.
Green Oil Well, Adams Cañon	9.0	0.762	54° B.	18.0	0.795	46° B.
Wild Bill, Adams Cañon	9.2	0.732	61° B.	10.8	0.813	42° B.
Puente	7.7	0.771	51° B.	10.2	0.803	44° B.

Locality from which Sample was Obtained.	Illuminating Oils—Continued.					
	Below 250° C.	Specific Gravity	Nearest Corresponding Degree to Scale.	Below 300° C.	Specific Gravity	Nearest Corresponding Degree to Scale.
Tar Creek	11.0%	0.889	33° B.	7.1%	0.889	27° B.
Sespe No. 2	9.0	0.822	40° B.	8.0	0.876	30° B.
Green Oil Well, Adams Cañon	14.4	0.832	38° B.	10.0	0.861	33° B.
Wild Bill, Adams Cañon	8.0	0.846	35° B.	7.7	0.880	29° B.
Puente	7.2	0.845	36° B.	6.0	0.881	29° B.

4.03. A review of these tables shows that the naphthas and distil-
s below 200° C. are practically absent from the Los Angeles and the
ımerland oils, and that the oils from Puente, the Sespe district, and
districts north of Santa Paula, not only yield naphthas, but a much
er percentage of the illuminating oils than do the oils from Los
eles and Summerland. Some of the samples of oil from Los
eles and Summerland and the sample from the Magie tunnel con-
ed water and held mineral matter in suspension.

4.04. With the following samples distillation was continued at
peratures of more than 350° C. The temperature was gradually
eased and the distillates, *a*, *b*, *c*, and *d*, were cut off in the order in
ch they are mentioned:

SAMPLE OF OIL FROM PUENTE OIL-WELLS.

(Specific gravity, 0.8893, or about 28° B.)

Temperature hich Distillates ere Cut Off.	Percentage by Volume.	Percentage by Weight.	Specific Gravity.	Nearest Degree to Scale.	Character of Distillate, Etc.
[illegible]	10.20	8.42	0.7323	61° B.	Naphtha.
[illegible]	13.47	11.67	0.7656	53° B.	Illuminating oil.
[illegible]	12.24	11.13	0.8089	43° B.	Illuminating oil.
[illegible]	10.20	9.67	0 8413	36° B.	Illuminating oil.
[illegible]	8.67	8.29	0.8502	34° B.	Gas distillate.
[illegible]	15.82	15.16	0.8529	34° B.	Gas distillate.
[illegible]	16.33	15.54	0.8469	35° B.	Gas distillate.
[illegible]	4.08	4.17	0.9090	24° B.	Lubricating oil.
		3 24			Residue.
		12.71			Loss.

PLE OF OIL FROM WELL OF CALIFORNIA OIL CO., IN THE SESPE DISTRICT. (Specific gravity, 0.9402.)

[illegible]	7.37	6.00	0.7649	53° B.	Illuminating oil.
[illegible]	9.47	8.07	0.8012	45° B.	Illuminating oil.
[illegible]	11.37	10.28	0.8506	34° B.	Illuminating oil.
[illegible]	2.95	2.70	0.8608	33° B.	Gas distillate.
[illegible]	19.48	18.45	0.8906	27° B.	Lubricating oil.
[illegible]	27.89	26.45	0.8914	27° B.	Lubricating oil.
[illegible]	6.11	5.57	0.8585	33° B.	Gas distillate
[illegible]	2.95	3.00	0.9479	18° B.	Lubricating oil.
		10.18			Residue.
		9.30			Loss.

PLE OF OIL FROM FOUR FORKS, SESPE DISTRICT. (Specific gravity, 0.9196.)

[illegible]	6.94	5.80	0.7684	52° B.	Illuminating oil.
[illegible]	16.84	14.64	0.8005	45° B.	Illuminating oil.
[illegible]	9.69	8.82	0.8396	38° B.	Illuminating oil.
[illegible]	6.63	6.21	0.8604	33° B.	Gas distillate.
[illegible]	15.51	14.31	0.8493	35° B.	Gas distillate.
[illegible]	37.14	36.37	0.8980	26° B.	Lubricating oil.
		4.72			Residue.
		9.13			Loss.

SAMPLE OF GREEN OIL FROM PINKERTON TUNNEL, SOUTH SIDE OF SULPHUR MOUNTAINS. (Specific gravity, 0.9333.)

Temperature at which Distillates were Cut Off.	Percentage by Volume.	Percentage by Weight.	Specific Gravity.	Nearest Degree to Scale.	Character of Distillate, Etc.
250° C.	11.6	9.26	0.8015	45° B.	Illuminating oil.
300° C.	16.0	14.41	0.8406	37° B.	Illuminating oil.
350° C.	5.0	4.62	0.8620	33° B.	Gas distillate.
(*a*)	17.0	16.23	0.8914	27° B.	Lubricating oil.
(*b*)	25.6	24.50	0.8925	27° B.	Lubricating oil.
(*c*)	11.6	10.53	0.8473	35° B.	Gas distillate.
(*d*)	6.0	6.18	0.9615	16° B.	Lubricating oil.
		4.29			Residue.
		9.28			Loss.

4.4.05. As is shown by the records of the distillations made at temperatures of more than 350° C., there was some decomposition, which resulted in the oil "cracking," and the formation of a distillate possessing a lower specific gravity than that of the preceding fraction. Nearly all the distillates obtained at and above a temperature of 350° C. had an offensive odor. The residuum consisted of a brilliant black material, a sample of which showed as follows:

Soluble in alcohol	1%
Soluble in ether	7
Soluble in carbon disulphide	6
Insoluble hydrocarbons	12
Fixed carbon	16
Ash	58

The loss during the process of distillation practically ranged from 9% to 12%; it resulted, no doubt, from the escape of steam and gas.

RESUME OF ORIGINAL RESEARCHES, ANALYSES, AND REFINING METHODS OF PETROLEUM, MAINLY FROM THE SOUTHERN COUNTIES OF CALIFORNIA.

By FREDERICK SALATHÈ, PH.D.

ORIGIN.

The opinions on the origin of petroleum still differ widely among chemists, but through the classic researches recently made by Engler, who has produced the complete series of paraffins, identical with the petroleum-hydrocarbons, by synthesis from fish oils under pressure during distillation, the theory of animal origin of petroleum has become most plausible.

The question has been asked, what has become of the nitrogen, if petroleum was formed of marine animals, and why are most of the petroleum-hydrocarbons free from nitrogen combinations?

Analysis of some natural gas from a well in Pennsylvania shows the presence of nitrogen in natural gas, which in one instance amounted to 23% by volume.

In 1892, I began an investigation on the hydrocarbon series constituting the Ventura County crude oils, which I found to contain invariably from 0.75% to 3.5% of nitrogen. The experiments were conducted in such a manner as to ascertain in what form or combination the nitrogen existed in the crude petroleum, with the view of isolating the nitrogenous hydrocarbons.

The result was the identification of a number of organic bases of the Pyridin and Chinolin series, which heretofore were only found in the so-called animal tar from the distillation of animal cadavers or bones.

The presence of these organic bases in the California petroleum indicates, therefore, clearly the origin of this petroleum from animal matter furnished by the slow decay of a marine fauna, which became extinct by changes of the sea-water through local influx of saline mother liquors.*

ELEMENTARY ANALYSIS.

The sample of crude petroleum represented an average mixture of Ventura County crude oils of 23.5° B., or 0.9120 specific gravity.

Carbon	84.0%
Hydrogen	12.7
Nitrogen	1.7
Oxygen	1.2
Sulphur	0.4
	100.0%

*Theory advanced by Oechoener, Engler, Zalociecke. More detailed reference will be found in a paper on the origin of petroleum, read by writer, April, 1894, before the Technical Society of the Pacific Coast.

CHEMICAL CONSTITUTION AND HYDROCARBON SERIES OF VENTURA AND LOS ANGELES COUNTIES CRUDE OILS.

These crude oils, which all carry asphalt, held in combination with the high boiling members of the hydrocarbon series, are of a very complex constitution, which makes their refining exceedingly difficult. By a series of chemical reactions and fractional distillations, I have succeeded in isolating various hydrocarbons, which define clearly the presence of the following hydrocarbon series:

(*a*) Hydrocarbons of the Paraffin, or fatty, series. C_nH_{2n+2}.

(*b*) Hydrides or hydron addition-products of the Benzole series. C_6H_{12} and homologous hydrocarbons.

(*c*) Pyridin and Chinolin series. $C_nH_{2n-5}N$ and $C_nH_{2n-11}N$.

(*d*) Isomeres of the Terpene series. C_nH_{2n-4}.

(*a*) *Hydrocarbons of the Paraffin series*, C_nH_{2n+2}. These were separated by successive treatment of crude oil and its fractions with fuming sulphuric acid containing 20% sulphuric anhydride in solution, nitric acid 43° B., chromic acid, potassium-hydrate, followed by fractional distillations. Owing to the great difficulty of isolating the high boiling members, whose boiling-points are very close together, I examined the fraction boiling between 80° and 100° C., and isolated and identified in the same *Heptane*, C_7H_{16} of 97° C. boiling-point. By chlorination and subsequent decomposition of the chlorides, Heptylic alcohol was formed. Crystallizable paraffin could not be detected in any of the heavy fractions. At 20° C. a slight cloudiness appeared in the oils, caused by the presence of traces of colloidal paraffin, such as constitutes the liquid paraffins in Eastern oils.

(*b*) *Hydrides of the aromatic or Benzole series*, C_nH_{3n-6}. These hydrocarbons could only be separated and identified from the residue obtained by the treatment of the original oil with fuming sulphuric acid, and were in form of sulpho-conjugated derivatives of the Benzole series, yielding, when melted with caustic potassa, Phenol and its homologous oxy-products, which I have under further investigation.

The great facility with which California oils produce, by pyrogenic action, Benzole and its homologues, which process the writer has especially studied, further illustrates the presence of hydrides of the aromatic series.

(*c*) *Pyridin and Chinolin series*, C_nH_{2n-5} and $C_nH_{2n-11}N$. I obtained and isolated this group of basic hydrocarbons by extraction of the California crude oil and its fractions with dilute sulphuric acid, 1:5, at 212° F. The acid solution containing the organic bases in the form of sulphates was then steamed until no more volatile oils, mainly Pyrrol, passed over with the aqueous vapors. The bases were then precipitated by potassium hydrate in form of yellowish-gray flocks, which, by prolonged heating on the waterbath, formed a supernatant oil of a reddish-brown color and of the characteristic penetrating odor of the Pyridin bases. The crude basic oils showed a specific gravity of 0.9985. By moderate oxidation with permanganate of potassium the basic hydrides were first converted into normal bases, while at the same time the formation of small quantities of *a* Pyridin-monocarbonic acid was observed derived from partial oxidation of the homologous bases of

Pyridin. The resulting bases were then dried over potassium hydrate and submitted to fractional distillations in the following fractions:

From 115° to 121° C.,	specific	gravity	= 0.9580
" 132° " 138° C.,	"	"	= 0.9610
" 137° " 170° C.,	"	"	= 0.9735
" 169° " 180° C.,	"	"	= 0.9890
" 179° " 200° C.,	"	"	= 1.0500
" 199° " 250° C.,	"	"	= 1.0860
" 249° " 320° C.,	"	"	= 1.1200

From fraction 115° to 121° C. pure Pyridin was isolated, by forming the insoluble Ferro-cyanide and the Platino-chloride combination. It distilled at the constant temperature of 116° C.

The next homologous base, the α Picolin or α Methyl-pyridin, was isolated from fraction 132° to 138° by converting the same into the Picolin-ferrocyanide combination, which is easily soluble in water, and which by double decomposition with alkali yielded α Picolin of 140° boiling-point.

The Pyridin and α Picolin showed all the characteristics of these bases made from animal tar. The higher homologous bases, such as Lutidin, Collidin, etc., have not yet been isolated by me except that their presence is indicated by the uniform rise in the boiling-points of fractions. In continuing the distillation above 300° C. considerable ammonia-gas is generated, which is formed by the action of the high temperature on the heavier basic products. All fractions above 200° C. possess a remarkable, fine crimson fluoresence. By carrying the distillation to 360° C., a glossy, hard, asphalt-like substance remains in the still; diluted sulphuric acid, 1:5, dissolves the same to the greatest part and alkalies precipitate from the filtered solution a crystalline powder which probably contains a number of unknown solid nitrogenous hydrocarbons of the Pyridin or Chinolin series, parallel with Anthracene, Phenanthrene, Chrysene, etc., from coal tar.

The presence of Chinolin and its homologues was demonstrated by the Cyanin reaction, a blue color, which is formed from the Iodin derivatives of Chinolin and its homologues.

The occurrence of Pyridin and Chinolin bases in California crude oils opens up a new resource for these products, which are largely used for the synthetical production of alkaloids, dyes, etc., and in a large measure for 'denaturalizing' alcohol in Europe.

(*d*) *Isomeric Hydrocarbons of the Terpene series*, C_nH_{2n-4}. These hydrocarbons enter easily into polymerization and thus form the greatest part of the asphaltic constituents usually termed Petrolene and Asphaltene, which terms I use instead of Retinoid and Retene; the former being a series of polymerized hydrocarbons, the latter their oxidation product.

The investigation on these hydrocarbons is not far enough advanced for publication.

(*e*) *Sulphureted Hydrocarbons.* These of the California crude oils differ in their chemical constitution from the sulphureted Trenton lime oils of Ohio or Canada, mainly in that the sulphur is for the greatest part only confined by chemical substitution to the highest boiling constituents, the asphalt, and is practically transferred by chemical action to *the middle fractions during distillation* in the form of sulphur-addition products, another part escaping in the form of sulphureted hydrogen.

Distillation over soda lime or passing the vapors over the same completely eliminates the sulphur from the hydrocarbons; this is not the case with Ohio or Canada oils.

PRACTICAL DISTILLATIONS AND YIELDS OF VARIOUS SOUTHERN CALIFORNIA CRUDE OILS.

1. *Sespe Oil*, of 25.2° B. or 0.9022 specific gravity at 60° F.

Naphtha, 60° B. at 150° C.	7.30%	
Illuminating distillate, 42° B. at 330° C.	19.50	
Gas distillate, 28° B.-above 360° C.	25.00	
Lubricating distillate, 24° B.-above 360° C.	35.80	
*Asphalt and Loss	12.40	
		100.00%

The Pyridin bases equal 2.30%.

2. *Crude Oil from Four Forks*, of 24° B. or 0.9090 specific gravity.

Naphtha	6.00%	
Illuminating distillate	17.10	
Gas distillate	29.50	
Lubricating distillate	34.40	
Asphalt and Loss	13.00	
		100.00%

The Pyridin bases equal 1.75%.

3. *Crude Oil from Torrey Cañon*, of 27° B. or 0.8917 specific gravity.

Naphtha	9.20%	
Illuminating distillate	21.50	
Gas distillate	26.00	
Lubricating distillate	30.30	
Asphalt and Loss	13.00	
		100.00%

The Pyridin bases equal 1.52%.

4. *Crude Oil from Lime Kiln Cañon* (Eureka Oil Co.), of 29° B. or 0.8805 specific gravity.

Naphtha	14.10%	
Illuminating distillate	26.40	
Gas distillate	24.00	
Lubricating distillate	27.00	
Asphalt and Loss	8.50	
		100.00%

The Pyridin bases equal 1.44%.

5. *Crude Oil from Adams' Cañon* (Tunnel Oil), greenish oil of 24° B. or 0.9090 specific gravity.

Naphtha	5.20%	
Illuminating distillate	24.50	
Gas distillate	17.30	
Lubricating distillate	46.00	
Asphalt and Loss	7.00	
		100.00%

The Pyridin bases equal 0.88%.

6. *Crude Oil from Los Angeles Wells*, of 14.2° B. or 0.9708 specific gravity.

Naphtha	Traces.	
Illuminating distillate	6.00%	
Gas distillate	17.50	
Lubricating distillate	51.50	
Asphalt and Loss	25.00	
		100.00%

The Pyridin bases equal 3.2%.

This crude oil contains usually from 2.5% to 7% of water and 0.16% to 2% of suspended mineral matter, mainly a fine silicious clay.

*The gravities of the products, Naphtha, etc., are the same in all the following analyses of crude oils, as in No. 1, Sespe oil.

7. *Fresno County Crude Oil, from Coalinga,* of 54° B. or 0.7608 specific gravity.

This oil represents a distillate made by nature, nearly all fractions having a very low fire test.

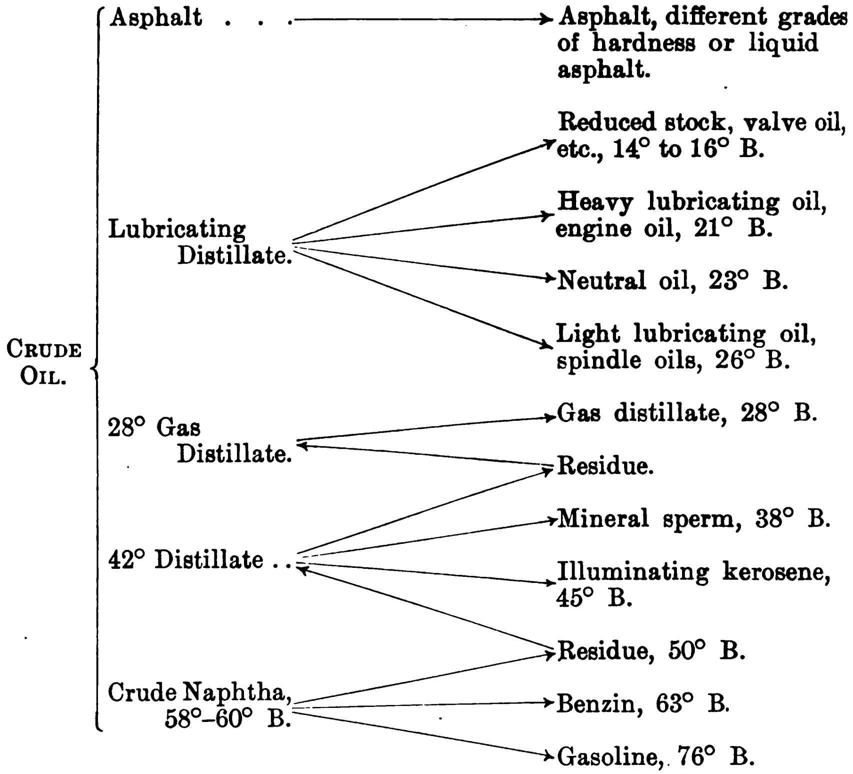
Fraction	1.	10%,	at	temperature	from	49°	to	111°	C.
"	2.	10%,	"	"	"	110°	"	121°	C.
"	3.	10%,	"	"	"	120°	"	141°	C.
"	4.	10%,	"	"	"	140°	"	161°	C.
"	5.	10%,	"	"	"	160°	"	176°	C.
"	6.	10%,	"	"	"	175°	"	196°	C.
"	7.	10%,	"	"	"	195°	"	227°	C.
"	8.	10%,	"	"	"	226°	"	249°	C.
"	9.	10%,	"	"	"	248°	"	275°	C.
"	10.	10%,	Residue is hard asphalt.						

REFINING.

From the investigations given so far it is evident that the refining of the crude California oils is not an easy task and that they require refining methods different from those practiced with Eastern or Russian oils.

The complicated nature of this class of asphaltic crude oils necessitates complete elimination of all unstable hydrocarbons by inexpensive practical processes. Another great difference exists between the specific gravities of Eastern oil distillates and those of California oils. Viscosity of distillate or reduced stock being equal, the gravities are from 5° to 6° B. lower in California oil fractions than in those of Eastern oils. Flash and fire tests are from 10° to 30° F. lower in California oil distillates than in Eastern distillates of the same gravity.

The following is a diagram of products available from California crude oil by refining, showing where redistillation is required:



The average yield of products from 100 bbls. of Ventura County mixed crude oil of 24° B., determined by actual running on a large scale, is as follows:

Gasoline, 76° B.	3	bbls.
Benzin, 63° B.	4	"
Kerosene, 45° B.	15	"
Heavy kerosene, 38° to 40° B.	8	"
Gas distillate, 28° B.	21	"
Light lubricating (spindle) oil, 26° B.	10	"
Neutral oil, 23° B.	12	"
Heavy neutral oil, 21° B.	6	"
Reduced stock, lubricating oil, 14° B.	5	"
Asphalt, crude.	11	"
Loss	5	"

The extraction of Pyridin bases with dilute sulphuric acid should be done before the redistillation of the distillates, as the treatment of those distillates with concentrated sulphuric acid will otherwise form certain sulpho-conjugated products which, during the washing process with water and alkali, decompose and re-enter into solution again with the refined products.

The special refining methods will be discussed in the next paper, as certain processes are not yet covered by letters-patent.

LIST OF FOSSILS. Identified by Dr. J. G. Cooper.

LOS ANGELES COUNTY.

Miocene, Pliocene, and Quaternary Fossils.	Los Angeles Oil-Wells	Well on Green-Meadow Ranch	Shatto Estate, West Los Angeles	Normal School, Los Angeles	Asphaltum Bed, Lincoln Park	Brea Cañon, Puente Hills	Santa Monica, East of Pier	Other Localities.	Geological Range.
Amycla gausapata Gould						X			L. Quat. Pl.?
Arca multicostata Sby.						X			L. Pl. Mioc.
Axinæa intermedia Brod.	X								L. Quat.
Bittium asperum Gabb				X					L. Quat. Pl.
Calliostoma costatum Martyn				X		X			L. Quat. Pl.
Carcharodon rectus Agassiz			X						Pl.
Cancellaria vetusta Gabb (*C. cassidiformis* Sowerby)			X	X					L. Quat. Pl. Mioc.
Cerithidea californica Haldeman	X								L. Quat. Pl. Mioc
Chama exogyra Con.	X					X			L. Quat. Pl.
Chemnitzia chocolata Carp.					X				L. Quat.
Chione mathewsoni Gabb						X			Pl. Mioc.
Chlorostoma pfeifferi Phil.							X		L. Quat.
Clathurella conradiana Gabb	X								Quat. Pl.
Corbula luteola Carp.				X					L. Quat.
Crepidula grandis Midd.	X		X	X					L.?Quat. Pl. Mioc.
Crucibulum spinosum Sowerby						X			Q. Pl. Mioc.
Cryptomya californica Con.			X	X		X			L. Quat. Pl. Mioc.
Cyathodonta undulata Con.						X			L. Quat. Mioc.
Cypricardia pedroana Con.		X	X	X					Quat.
Drillia n. sp.?								Hays Cañon	(Perhaps Eocene)
Diplodonta orbella Gould				X					L. Quat. Pl.
Fusus kobelti Dall.						X			L. Quat. Pl. Mioc.?
Galerus inornatus Gabb						X			Pl. Mioc.
Glycimeris generosa Gould						X			L. Quat. Pl. Mioc.
Hinnites giganteus Gray	X								L. Quat. Pl. Mioc.
Janira bella Con.				X		X			Pl. Mioc.
Kellia suborbicularis Montagu		X	X	X			X	Reynolds & Wiggins well, Los Angeles	L. Quat. Pl.
Laqueus californicus Koch								Temescal Cañon	L. Quat. Pl.
Lithophagus plumula Reeve				X					L. Pl.

LOS ANGELES COUNTY—Continued.

Miocene, Pliocene, and Quaternary Fossils.	Los Angeles Oil-Wells	Well on Green-Meadow Ranch	Shatto Estate, West Los Angeles	Normal School, Los Angeles	Asphaltum Bed, Lincoln Park	Brea Cañon, Puente Hills	Santa Monica, East of Pier	Other Localities.	Geological Range.
Litorina scutulata Gould						X	X		Pl. Mioc.
Lucina californica Con.			X						L. Quat.
Lutricola alta Con.						X			L. Quat. Pl. Mioc.
Macoma inquinata Desh.	X								L. Quat. Pl.
Macoma nasuta Con.	X			X					L. Quat. Pl. Mioc.
Mera modesta Carp.						X			L. Quat. Pl. Mioc.
Mercenaria perlaminosa Con.						X			L.?Quat. Pl. Mioc.
Mitra maura Swainson	X								L. Quat. Mioc.
Mytilus pedroanus Con.						X			Quat. Pl.
Nassa fossata Gould		X		X					L. Quat. Pl. Mioc.
Nassa (var. *californiana* Con.)				X					L. Quat. Pl.
Nassa mendica Gould		X		X					L. Quat. Pl.
Nassa perpinguis Hinds		X				X			L. Quat. Pl. Mioc.?
Neptunea humerosa Gabb					X				Pl.
Neverita callosa Gabb							X		Mioc.
Neverita recluziana Petit								First & Olive sts., L. A.	L. Quat. Pl.
Nucula exigua Sowerby						X			L. Quat. Pl. Mioc.
Ocinebra lurida Midd.		X							L. Quat. Pl.
Olivella intorta Carp. (*O. pedroana* Con.?)							X		L. Quat. Pl.
Ostrea titan Con.						X		Brown's Cañon	Mioc.
Ostrea vespertina Con.	X								Pl.
Oxyrhina plana Agassiz			X						Pl.
Oxyrhina tumula Agassiz			X						Pl.
Petricola carditoides Con.							X		L. Quat.
Pecten expansus Dall.						X		Temescal Cañon	Pl.
Pecten pedroanus Trask				X				Clark Est., Los Ang.	Pl.? Mioc.
Pecten stearnsii Dall.								Hays Cañon, Brown's Cañon	Pl.
Periploma discus Stearns								First & Olive sts., L. A.	L. Quat.
Placunanomia n. sp.?	X								
Platyodon cancellatus Con.	X				X				L. Quat. Pl.
Saxidomus gibbosus Gabb			X						Pl.
Saxidomus gracilis Gld.							X		L. Quat. Pl. Mioc.
Schizotherus nuttalli Con.							X		L. Quat. Pl.

Standella californica Con.			X	X					L. Quat. Pl. Mioc.
Tapes staleyi Gabb			X				X		Pl.
Tellina idæ Dall				X					L. Quat.
Turritella jewetti Carp.					X				L. Quat. Pl.
Terebratella occidentalis Dall						X		Temescal Cañon	L. Pl. Mioc.
Venericardia borealis Con.								Reynolds & Wiggins well, Los Angeles	L. Quat. Pl. Mioc.

LIST OF FOSSILS. Identified by Dr. J. G. Cooper—Continued.

VENTURA COUNTY. (Sespe Oil District to Aliso Cañon.)

Miocene, Pliocene, and Quaternary Fossils.	Tar Creek, Dark-Colored Shales and Hard, Calcareous Strata	Divide between Tar Creek and Stony Corral Creek.	East Fork of Corey Cañon.	Aliso Cañon	Goat Mountain, near Mouth of Adams Cañon.	Santa Paula Creek, between Mupu School-House and Sulphur Mts.	Other Localities.	Geological Range.
Acila castrensis Hinds								L. Quat. Pl.
Amycla tuberosa Carp.				X				L. Quat. Pl.
Astrodapsis whitneyi Con.						X		Pl.
Axinea intermedia Brod.						X		L. Quat. Pl.
Balanus estrellanus Con.	X						Divide between Kentuck and Brownstone oil-wells	Mioc.
Bittium asperum Gabb					X		Dark-colored shale, Corey Cañon	L. Quat. Pl.
Cardium centifilosum Carp.						X		L. Quat. Pl. Mioc.
Cardium corbis Con.					X			L. Quat. Pl.
Cardium quadragenarium Con.			X					L. Quat. Pl.
Cardium panamense Sowerby						X		L. Quat. Pl.
Chione mathewsoni Gabb						X		Mioc.
Chione pertenuis Gabb	X	X						Mioc.

VENTURA COUNTY—Continued.

Miocene, Pliocene, and Quaternary Fossils.	Tar Creek, Dark-Colored Shales and Hard, Calcareous Strata	Divide between Tar Creek and Stony Corral Creek.	East Fork of Corey Cañon.	Aliso Cañon	Goat Mountain, near Mouth of Adáms Cañon.	Santa Paula Creek, between Mupu School-House and Sulphur Mts.	Other Localities.	Geological Range.
Chione whitneyi Gabb.						X		Mioc.
Chlorostoma brunneum Phil.	X	X						L Quat. Pl.
Clidiophora punctata Con.					X			L. Quat. Pl. Mioc.?
Columbella richthofeni Gabb.					X			Pl.
Crepidula grandis Midd.					X		Soft sandstone, mouth of Corey Cañon	L.?Quat. Pl. Mioc.
Cryptomya californica Con.					X			L. Quat. Pl. Mioc.
Dentalium n. sp.?							Dark-colored shale, Corey Cañon	
Dentalium semipolitum Brod.						X		L. Quat. Pl.
Echinarachnius excentricus Esch.	X					X		L. Quat. Pl.
Echinarachnius n. sp.?	X							
Galerus inornatus Gabb.						X		Mioc.
Glycimeris generosa Gould					X			L. Quat. Pl. Mioc.
Heterodonax bimaculatus Desh.			X					L. Quat. Pl. Mioc.
Hinnites giganteus Gray	X							L. Quat. Pl. Mioc.
Hipponyx cranioides Carp.						X		L. Quat. Pl.
Lacuna solidula Loven.					X			L. Quat. Pl.
Lyonsia californica? Con.								L. Quat. Pl. Mioc.
Lunatia lewisii Gould					X			L. Quat. Pl.
Lutricola alta Con.					X			L. Quat. Pl. Mioc.
Macoma n. sp.?						X		
Mitra maura Swainson					X			L. Quat. Pl.
Modiola recta Gould					X			L. Quat. Pl. Mioc.
Monoceros lugubre Sowerby						X		L. Quat. Pl.
Muricidea paucivaricata Gabb					X			Quat. Pl.
Mytilus californianus Con.			X					L. Quat. Pl.
Myonera n. sp.				X				
Nassa (var. *californiana* Con.)					X			L. Quat. Pl. Mioc.

Nassa mendica (var. *cooperi* Gould & Forbes)						X		L. Quat. Pl.
Nassa perpinguis Hinds			X		X			L. Quat. Pl. Mioc.?
Neptunea altispira Gabb					X			Pl.
Neverita callosa Gabb	X	X						Mioc.
Neverita recluziana Petit							Turner's Cañon, foot-hills S. of Mt. Cayetana	L. Quat. Pl. Mioc.
Olivella biplicata Sby.							Turner's Cañon, foot-hills S. of Mt. Cayetana	L. Quat. Pl.
Olivella pedroana Con. (*O. intorta* Carp.)					X		Soft sandstone, mouth of Corey Cañon	L. Quat. Pl.
Ostrea bourgeoisi Rem.							Hard sandstone, S. slope Mt. Cayetana	Pl.
Ostrea sp.	X							
Pecten hastatus Sby.	X	X						L. Quat. Pl. Mioc.
Pecten pedroanus Trask (*P. peckhami* Gabb?)							Magie oil-tunnel	Mioc. Pl.?
Pholadidea ovoidea Gould			X					L. Quat. Pl.
Pisania fortis Carp.			X					Quat. Pl.
Placunanomia macroschisma Midd.	X				X			L. Quat. Pl.
Psephis tantilla Gould (*P. lordi* Baird?)					X			L. Quat. Pl.
Schizotherus nuttalli Con.					X			L. Quat. Pl.
Semele n. sp.					X			
Siliquaria edentula Gabb						X		Pl.
Solarium sp.				X				
Solen rosaceus Carp.				X	X	X		L. Quat. Pl. Mioc.
Standella planulata Con.					X			L. Quat. Pl. Mioc.
Surcula carpenteriana Gabb			X					L. Quat. Pl.
Tellina congesta Con.								Mioc.
Tellina idæ Dall.					X			L. Quat. Pl.?
Triton gibbosus Brod.			X		X		Dark-colored shale, Corey Cañon	L. Quat. Pl.
Trophon ponderosus Gabb						X		Mioc.
Turbonilla n. sp.?						X		
Turritella hoffmani Gabb	X	X						Mioc.
Turritella jewetti Carp.					X			L. Quat. Pl.
Turritella inezana Con.			X					Mioc.
Yoldia impressa Con.				X				L. Quat. Pl. Mioc.
Radiata, fragments of							Magie oil-tunnel	
Helix traski var. *carpenteri* Newcomb (from calcareous tufa)							Wheeler Cañon	L. Quat.

LIST OF FOSSILS. Identified by Dr. J. G. Cooper—Continued.

Fossils from Eocene Formation. (Heretofore classified as Cretaceous B.)	VENTURA COUNTY.							Santa Barbara County.	List of Fossils—Cretaceous Groups to which these Fossils have Heretofore been Referred.
	Divide between Tar Creek and Maple Creek	Tar Creek, Dark-Colored Shales and Hard, Calcareous Strata	Mt. San Cayetana, above Pine Creek	Mouth of Stony Corral Creek	Clay Beds, Santa Paula Creek, Silverthread Oil District	Station D, Hard Sandstones, Silverthread Oil District	Other Localities in Ventura County.		
Anatina n. sp.					X				Tejon.
Cardita alticosta Gabb							Ridge between Kentuck Wells and Little Sespe Cañon		Tejon.
Cardita planicosta Lamarck				X		X		Santa Monica oil-well	Tejon.
Cardium breweri Gabb			X	X			Axis of Cold Water anticline, near head of east fork of Santa Paula Creek		Tejon.
Cardium linteum Con.					X				Tejon.
Chemnitzia n. sp.					X				Tejon.
Corbula n. sp.					X				Tejon.
Cordiera microptigma Gabb							Mt. Cayetana, east of Santa Paula Creek		Tejon.
Dentalium cooperi Gabb					X				Tejon.
Dosinia (casts)		X							Tejon.
Euspira alveata Con.				X			Mt. Cayetana, east of Santa Paula Creek		Chico, Tejon.
Leda Gabbi Con.					X				Tejon.
Leda n. sp.					X				Tejon.
Lucina subcircularis Gabb							Clay shale, mouth of Bear Cañon, Santa Paula Creek		Chico, Texas Flat.
Meretrix californiana Con.					X				Tejon.
Meretrix horni Gabb			X						Tejon.
Meretrix uvasana Con.		X							Tejon.
Modiola major Gabb			X						Tejon.
Modiola ornata Gabb		X							Tejon.
Morio tuberculatus Gabb							Mt. Cayetana, east of Santa Paula Creek		Tejon.
Nassa cretacea Gabb					X				Tejon.

[illegible] Gabb					X				Tejon.
Nucula truncata Gabb					X				Chico.
Nucula solitaria Gabb					X				Tejon.
Ostrea idriaensis Gabb			X	X		X	Hard sandstone near granitic rocks, Agua Blanca Creek, Sespe District. Red Rock Peak. Axis of Cold Water anticline, near head of east fork of Santa Paula Creek.	Santa Monica oil-well, Rincon Creek, N. of Shepherd's Hotel	Tejon.
Ostrea sp.									Tejon.
Pecten martinezensis Gabb	X	X			X	X	Ridge between Kentuck wells and Little Sespe Cañon. Axis of Cold Water anticline, near head of east fork of Santa Paula Creek		Tejon.
Pecten interradiatus Gabb					X				Tejon.
Pecten n. sp.					X				Tejon.
Perna excavata White (*Perna montana* Con.? Mioc.)		X							Tejon.
Pholadomya progressiva Cooper	X					X	Clay shale, mouth of Bear Cañon, Santa Paula Creek		Tejon.
Siphonodentalium pusillum Gabb							Clay shale, mouth of Bear Cañon. Magie oil-tunnel		Tejon.
Solen parallelus Gabb					X				Tejon.
Spirocrypta pileum Gabb					X				Tejon.
Tellina æqualis Gabb		X							Tejon.
Tellina hoffmaniana Gabb					X				Tejon.
Tellina longa Gabb					X				Tejon.
Tellina parilis Gabb					X				Tejon.
Tellina quadrata Gabb							Clay shale, mouth of Bear Cañon, Santa Paula Creek. Magie oil-tunnel		Chico, Tejon.
Thracia semiplanata Whiteaves					X				Tejon.
Trachytriton tejonensis Gabb	X	X					Clay shale, mouth of Bear Cañon, Santa Paula Creek		Tejon.
Turritella chicoensis Gabb							Bowlder in conglomerate in Aliso Cañon		Chico, Tejon.
Turritella uvasana Con.	X	X							Tejon
Whitneya ficus Gabb							Mt. Cayetana, east of Santa Paula Creek		Tejon.
Yoldia arata Whiteaves					X				Tejon.
Yoldia nasuta Gabb					X				Tejon.

EOCENE FOSSILS FROM HAY'S CAÑON, CAHUENGA RANGE, LOS ANGELES COUNTY.

Pecten martinezensis Gabb. *Corbula horni* Gabb. *Cardita alticosta* Gabb. *Meretrix californiana?* Con.

LIST OF FOSSILS. Identified by Dr. J. G. Cooper—Continued.

SANTA BARBARA COUNTY (Punta Gorda R. R. Depot to Carpinteria). VENTURA COUNTY (Ventura City and Ventura River).

Miocene, Pliocene, and Quaternary Fossils.	Soft Sandstone Overlying Bleached Shale, Near Mouth of Rincon Creek	Soft Sandstone, Near Rincon Asphaltum Mine	Water-well, Higgins' Ranch	Oil-well, Higgins' Ranch	Other Localities.	Geological Range.
Acmea scabra Nutt.	X					L. Quat.
Amycla carinata Hds.	X		X			L. Quat.
Amycla gausapata Gld.	X				Soft sandstone, Ventura	L. Quat. Pl.?
Amycla tuberosa Carp.	X		X			L. Quat. Pl.?
Anomia lampe Gray	X					L. Quat. Pl.
Bittium asperum Gabb	X					L. Quat.
Bittium filosum Gould	X					L. Quat.
Cardium meekianum Gabb		X				Pl.
Cardita ventricosa Gould	X				Soft sandstone, Ventura	L. Quat.
Cardium quadragenarium Con.	X					L. Quat. Pl.
Chemnitzia	X					L. Quat.
Chrysodomus dirus Reeve	X					L. Quat.
Chlorostoma pfeifferi Phil.	X		X			L. Quat.
Clathurella conradiana Gabb	X					L. Quat. Pl.
Conus californicus Hinds	X	X				L. Quat. Pl.
Crepidula grandis Midd.	X	X				L. Quat. Pl.
Crepidula navicelloides Nutt.	X	X				L.Quat. Pl. Mioc.
Cryptomya californica Midd.		X				L.Quat. Pl. Mioc.
Drillia penicillata Carp.		X				L. Quat.
Echinus (spine of)	X					
Fusus kobelti Dall.		X				L. Quat. Pl.
Glycimeris generosa Gould	X					L.Quat. Pl. Mioc.
Hinnites giganteus Gray	X					L.Quat. Pl. Mioc.
Janira bella Con.	X					Pl. Mioc.?
Leptothyra carpenteri Pilsb. (*L. sanguinea* Cpr.)	X					L. Quat.
Lazaria subquadrata Carp.			X			L. Quat.
Lucina californica Con.	X		X			L. Quat. Pl.
Lunatia pallida Brod. & Sowerby	X	X				L. Quat. Pl. Mioc.
Macoma gouldi Hanley					Whitish sandstone, Ventura River	L. Quat. Pl.
Macoma inquinata Desh.		X				L. Quat. Pl.

Mercenaria perlaminosa Con.	X					L. Quat. Pl. Mioc.
Mitra maura Swainson	X					L. Quat.
Nassa mendica Gld.		X				L. Quat. Pl.
Nassa perpinguis Hds	X					L. Quat. Pl. Mioc.
Natica clausa Brod. & Sowerby	X					L. Quat.
Ocinebra lurida Midd.		X				L. Quat. Pl.
Olivella biplicata Swby.	X		X			L. Quat. Pl.
Olivella intorta Carp. (*O. pedroana* Con.? p.)	X				Soft sandstone, Ventura	L. Quat. Pl.
Opalia borealis Gould					Weldon Asphaltum Mine	L. Quat. Pl.
Pecten æquisulcatus Carp.	X					L. Quat.
Pecten islandicus Muller	X					L. Quat. Pl.
Pecten pedroanus Trask					Oil-well, Higgins' Ranch	Mioc.
Pisania fortis Carp.	X					Quat.
Pholadidea penita Con.	X					L. Quat. Pl.
Pomaulax undosus Wood	X					L. Quat.
Schizotherus nuttalli Con.	X		X			L. Quat. Pl.
Saxicava sp.	X					
Saxidomus gracilis Gould	X		X		Whitish sandstone, Ventura River	L. Quat. Pl. Mioc.
Semele bicolor Adams	X					L. Quat.
Siphonalia kelletti Forbes	X				Soft sandstone, Ventura	L. Quat.
Solen sicarius Gould	X					L. Quat. Pl. Mioc.
Surcula tryoniana Gabb	X	X				L. Quat. Pl.
Tapes staminea Con. (var.)	X					L. Quat. Pl. Mioc.
Tellina congesta Con.					Whitish sandstone, Ventura River	Mioc.
Turritella jewetti Carp.	X		X		Soft sandstone, Ventura	L. Quat. Pl.
Venericardia ventricosa Gld.		X			Whitish sandstone, Ventura River	L. Quat. Pl. Mioc.

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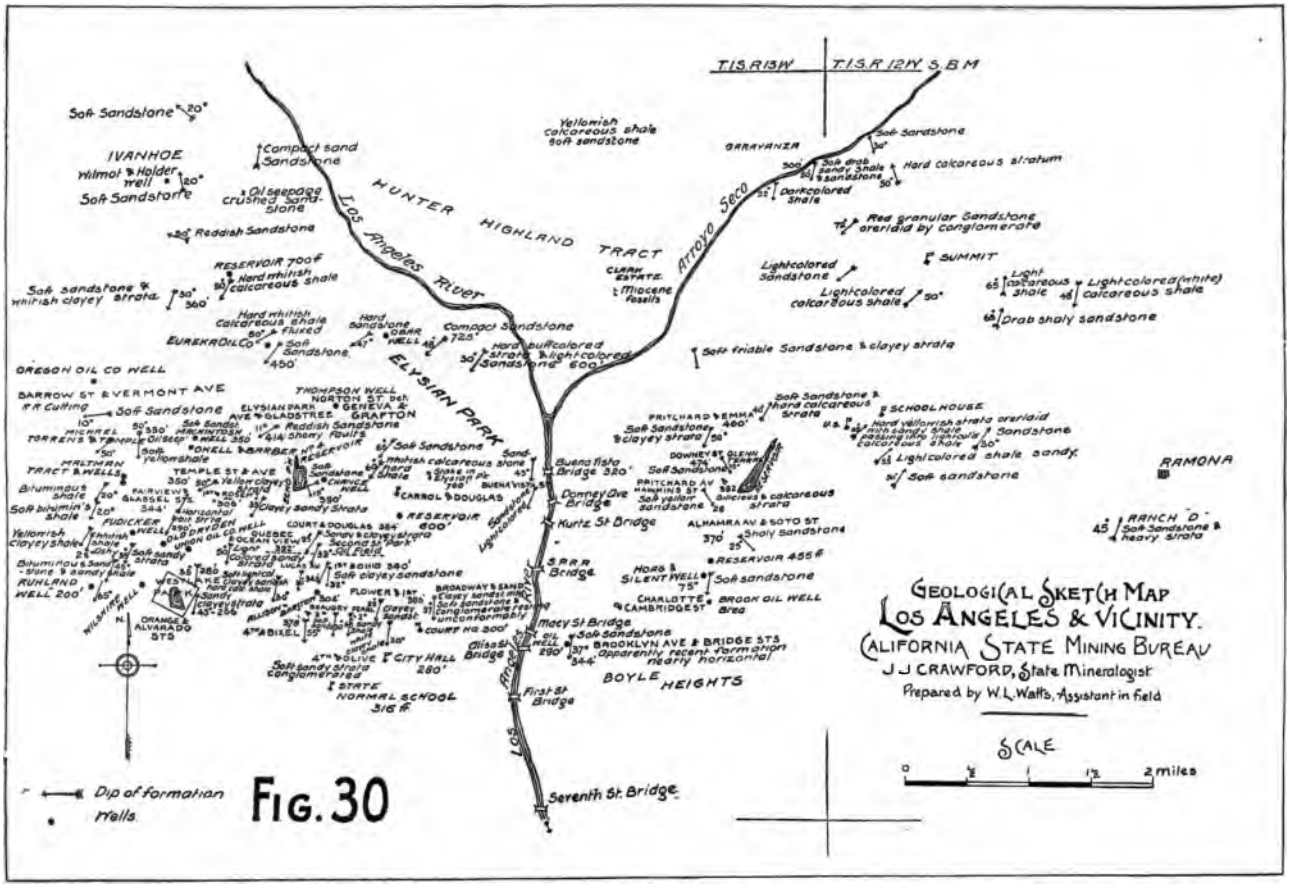

GEOLOGICAL SKETCH MAP
LOS ANGELES & VICINITY.
CALIFORNIA STATE MINING BUREAU
J J CRAWFORD, State Mineralogist
Prepared by W. L. Watts, Assistant in field
SCALE
0
1/2
1
1 1/2
2 miles
Dip of formation
Wells
T.1S.R13W
T.1S.R12W S.B.M
Los Angeles River
Arroyo Seco
HUNTER HIGHLAND TRACT
ELYSIAN PARK
BOYLE HEIGHTS
IVANHOE
GARAVANZA
SUMMIT
RAMONA
RANCH "D"
SCHOOL HOUSE
OREGON OIL CO WELL
EUREKA OIL CO
RESERVOIR 700 ft
RESERVOIR 455 ft
THOMPSON WELL
Buena Vista Bridge 320'
Downey Ave Bridge
Kurtz St Bridge
S.P.R.R. Bridge
Macy St Bridge
Aliso St Bridge
First St Bridge
Seventh St. Bridge
CITY HALL 280'
STATE NORMAL SCHOOL 316 ft
BROOK OIL WELL
BROOKLYN AVE & BRIDGE STS Apparently recent formation nearly horizontal
Soft Sandstone
Compact sand Sandstone
Oil seepage crushed Sandstone
Reddish Sandstone
Hard whitish calcareous shale
Yellowish calcareous shale Soft sandstone
Hard calcareous stratum
Red granular Sandstone overlaid by conglomerate
Lightcolored calcareous shale
Drab shaly sandstone
Soft friable Sandstone & clayey strata
Lightcolored shale sandy
Soft sandstone & heavy strata
Miocene fossils

FIG. 30

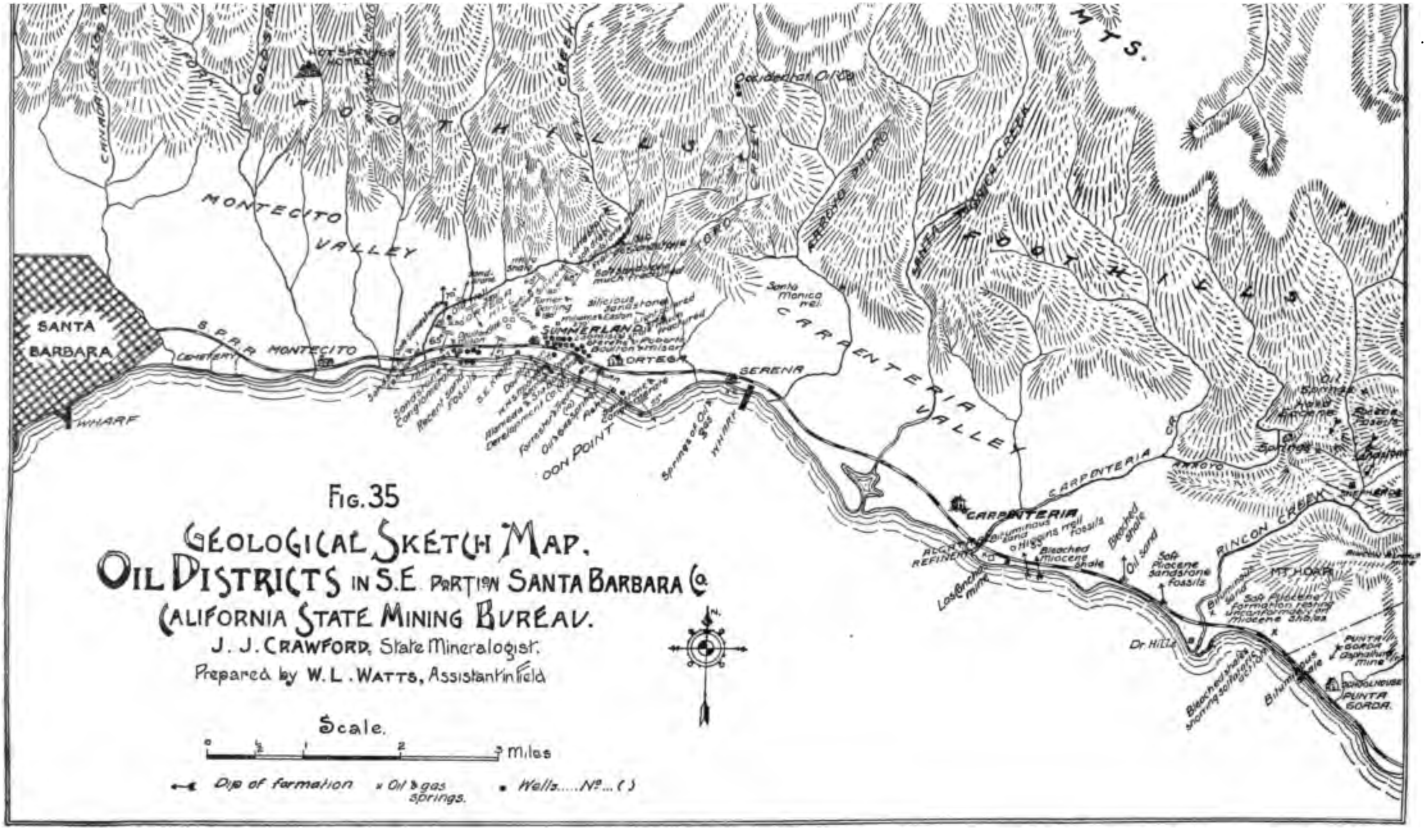
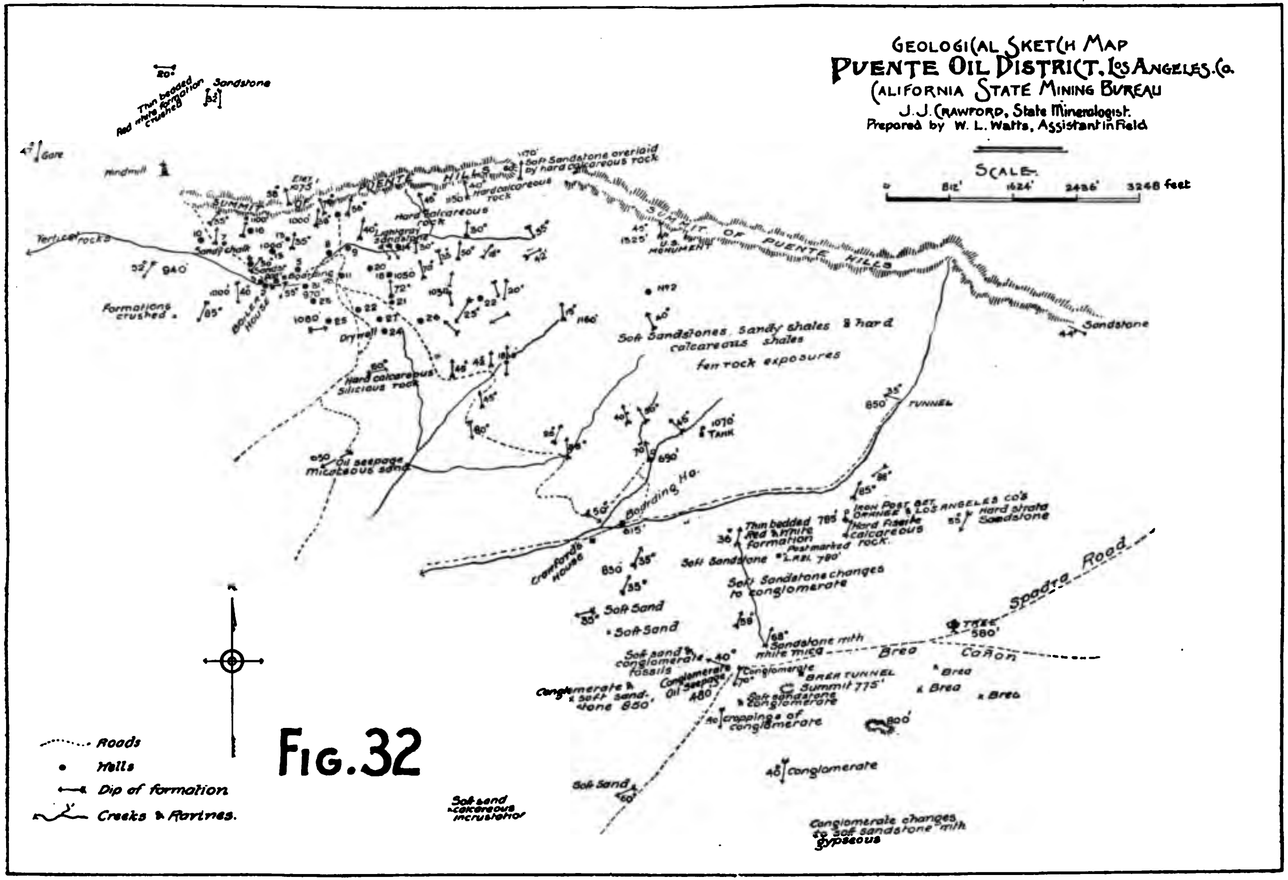


Fig. 35
GEOLOGICAL SKETCH MAP.
OIL DISTRICTS IN S.E. PORTION SANTA BARBARA Co.
CALIFORNIA STATE MINING BUREAU.
J. J. CRAWFORD, State Mineralogist.
Prepared by W. L. WATTS, Assistant in Field

Scale.
0 ½ 1 2 3 miles

Dip of formation × Oil & gas springs. • Wells.....No...( )



GEOLOGICAL SKETCH MAP
PUENTE OIL DISTRICT, LOS ANGELES CO.
CALIFORNIA STATE MINING BUREAU
J. J. CRAWFORD, State Mineralogist.
Prepared by W. L. Watts, Assistant in Field
SCALE
0
812'
1624'
2436'
3248 feet
Summit of Puente Hills
Puente Hills
Soft Sandstone overlaid by hard calcareous rock
Hard calcareous rock
Tertiary rocks
Formations crushed
Boarding House
Drywell
Hard calcareous Siliceous rock
Oil seepage micaceous sand
Soft Sandstones, Sandy shales & hard calcareous shales
few rock exposures
U.S. Monument
Tunnel
Tank
Boarding Ho.
Crawford's House
Thin bedded Red & white formation
Soft Sandstone
Soft Sandstone changes to conglomerate
Soft Sand
Sandstone with white mica
Brea Cañon
Spadra Road
Tree
Brea Tunnel
Summit 775'
Soft sandstone & conglomerate
Croppings of conglomerate
Conglomerate
Conglomerate changes to soft sandstone with gypseous
Brea
Sandstone
Windmill
Roads
Wells
Dip of formation
Creeks & Ravines.

FIG. 32